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ACL surgery: reasons for failure and management

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- Despite the general success of anterior cruciate ligament reconstructions (ACL-R), there are still studies reporting a high failure rate. Orthopedic surgeons are therefore increasingly confronted with the treatment of ACL retears, which are often accompanied by other lesions, such as meniscus tears and cartilage damage and which, if overlooked, can lead to poor postoperative clinical outcomes.
- The literature shows a wide variety of causes for ACL-R failure. Main causes are further trauma and possible technical errors during surgery, among which the position of the femoral tunnel is thought to be one of the most important.
- A successful postoperative outcome after ACL-revision surgery requires good preoperative planning, including a thorough evaluation of patient's medical history, e.g. instability during daily or sports activity, increased general joint laxity, and hints for a low-grade infection. A careful clinical examination should be performed. Additionally, comprehensive imaging is necessary. Besides a magnetic resonance imaging, a CT scan is helpful to determine location of tunnel apertures and to analyze for tunnel enlargement. A lateral knee radiograph is helpful to determine the tibial slope.
- The range of surgical options for the treatment of ACL-R failure is broad today. Orthopedic surgeons and experts in Sports Medicine must deal with various possible associated injuries of the knee or unfavorable anatomical conditions for ACL-R.
- The aim of this review was to highlight predictors and reasons of failures of ACL-R as well as describe diagnostic procedures to individualize treatment strategies for improved outcome after revision ACL-R.

Keywords

- causes of graft failure
- ACL reconstruction
- ACL revision
- ACL revision management

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Introduction

Anterior cruciate ligament (ACL) tears are one of the most commonly sustained knee injuries, with an estimated incidence of 200 000 per year only in the USA (1, 2). In young, active patients, ACL reconstruction (ACL-R) is the treatment of choice (3, 4, 5). Long-term objective and patient-reported outcome measures (PROMs) have gradually improved over the last decades (6), though, good and very good outcomes are achieved in 75–97% of patients (7, 8, 9, 10, 11).

Failure of ACL-R is defined by a history of previous primary ACL-R with a new onset of clinical symptoms such as instability and possibly giving way episodes. Additionally, positive Lachman and/or pivot shift tests are expected. The diagnosis of graft rupture or insufficiency can be confirmed by stress radiographs due to quantification of anterior tibial translation. Magnetic resonance imaging (MRI) can detect graft rupture but has limitations to show graft insufficiency. However, indirect signs such as an increase in posterior cruciate ligament (PCL) angulation might be of help. ACL graft failure remains a concern since a subset of patients experience recurrent instability after reconstruction (3–14%) (12, 13, 14).

The goal of ACL revision surgery is a stable, pain-free knee with near full range of motion (ROM) paying special attention to full extension, allowing sports and unrestricted daily activities according to the patient's specific pre-injury functional demands, decreasing the risk of secondary injuries such as meniscus tears (6). However, the literature has shown that the outcome of revision ACL-R is less predictable compared to primary ACL-R, resulting in poorer PROMs, a higher rate of recurrent instability and re-ruptures, as well as a lower rate of return to sports (RTS) compared to patients after primary ACL-R (15, 16).

Reasons of failure

The reason for graft failure after ACL-R has been assumed to be multifactorial (17, 18, 19). Thus, it often remains difficult to find the one reason for the failure of an ACL-R (20). Several epidemiological and individual factors have been suggested to contribute to an increased risk of failure such as younger age, graft choice, graft thickness low compliance during rehabilitation (21, 22), technical errors, and so on (Fig. 1). However, to shed more light into this topic, some recent studies investigated the incidence and major causes of ACL-R failure, including failure modes, graft types, and tunnel positions (19, 23, 24).

One of the most recent review articles included 24 cohort studies and 4 registry-based studies identifying a total of 3657 failures (19). The most common single failure mode of ACL-R was new trauma (38%), followed by technical errors (22%), combined causes (i.e., multiple failure mechanisms, 19%), and biological failures (i.e., failure due to infection or laxity without traumatic or technical causes, 8%). Technical errors also played a contributing role in 17% of all failures.

Regarding technical errors, femoral tunnel malpositioning was the main cause (63%), followed by tibial tunnel malpositioning (7%), and 29% remained unspecified. Other causes were observed less frequently, e.g. malpositioning of both tunnels (2%), graft fixation (2%), and tunnel enlargement (1%). Malposition of a tunnel means a non-anatomic tunnel position, where the position of the aperture of the bone tunnel is not in the footprint of the native ACL. This non-anatomic tunnel position is thought to result in an inferior biomechanical stability and thus in an increased risk of ACL failure. When comparing the transtibial (TT) and the anteromedial (AM) portal technique to drill the femoral bone tunnel, it was shown that technical errors including tunnel malpositioning, fixation difficulty, excessive or weak graft tensioning, concomitant untreated laxity, and other pathologies were more often inappropriately addressed (49 vs 26%). A more vertical femoral tunnel, as created with the TT technique, is associated with a higher incidence of graft failure (loss of rotational stability and higher risk of elongation over time). To allow for a more anatomic femoral tunnel placement, recent studies have focused on the superior outcomes of the AM technique than the TT technique (25, 26). The TT technique positions the aperture of the femoral tunnel positions more anteriorly, resulting in a more vertical aligned graft that allows greater anteroposterior (AP) translation and rotation compared to a more horizontally aligned graft. This greater rotational instability increases shear stress on ACL-R, cartilage, and menisci, which increases the risk of ACL re-rupture and wear (27, 28, 29). The higher re-rupture rate of more anteriorly placed femoral tunnel apertures was also shown in a recent subanalysis of a randomized controlled trial with a follow-up of about 11 years (30). This study identified a safe zone parallel to the Blumensaat line at the most posterior 35% of the femoral condyle. These findings provide guidance to surgeons for more precise and accurate surgery and reconstruction of a long-lasting graft.

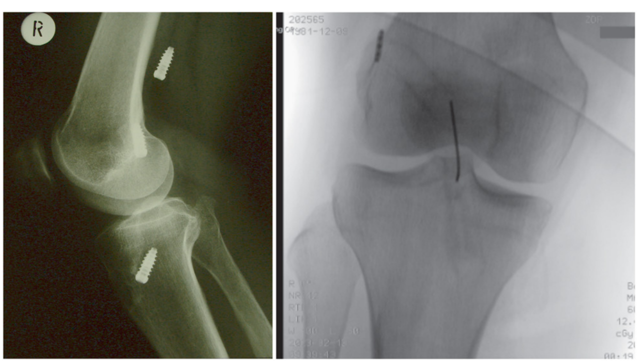

Figure 1
Technical errors. Left – malplaced femoral screw left in situ. Right – broken nitinol wire in the ACL graft.

Overlooked pathologies during primary ACL-R that might be responsible for ACL-R failure are another entity of technical errors, e.g. PCL ruptures or meniscus injuries. For example, posterolateral meniscal root tears are found in one-fifth of patients during ACL revision surgeries (31). Posterolateral root tears in patients with torn ACL increase AP and rotational laxity compared to isolated torn ACL (32, 33). Repair of the posterolateral root resulted in good PROMs and high healing rates (90%), whereas neglecting these injuries results in lateral joint space narrowing (34, 35, 36, 37). Recently, meniscus ramp lesions were highlighted as a potential risk factor for ACL-R failure, if left untreated. Meniscus ramp is the ligamentous connection between the posterior horn of the medial meniscus and the posteromedial tibial head as well as the posteromedial capsule (38). In about 9–15% of patients with ACL tears, these meniscus ramp lesions occur (39, 40). By looking at the literature, some authors mentioned higher numbers, but this is because these authors also included peripheral vertical longitudinal meniscus tears and counted them as ramp lesions. This is based on a classification, where both pathologies, true ramp lesions and vertical peripheral longitudinal meniscus tears, were recently counted as ramp lesions (41). The biomechanical studies are controversial (42), and the clinical studies failed so far to show an advantage of repairing ramp lesions compared to arthroscopic refreshing. There is one published RCT with

73 patients that did not show an advantage to repair after a minimum follow-up of 2 years (43). There were several case series published stating that ramp lesion should be repaired to decrease the risk of ACL-R and medial meniscus failure (44, 45). However, in the method sections of these papers, the authors described that besides ramp lesion, also classic vertical longitudinal meniscus tears were included. It is well known that these vertical longitudinal tears should be repaired, but by adding these meniscus tears it remains still unclear whether ramp lesions require routine repair (45).

Graft choice is one of the most debated topics in this field. Allografts when compared to autografts were shown to have a distinct higher failure rate especially in young, active patients (46). Regarding autografts, in general, bone–patellar tendon–bone (BPTB) grafts seem to have a lower failure rate; and hamstring (HT) grafts less harvest morbidity (47, 48). Nevertheless, there have been plenty of studies showing similar results of both grafts (49). In recent years, quadriceps tendon (QT) autograft has gained more attention, which can be harvested with or without a patellar bone block. The results of a systematic review and meta-analysis (2856 patients in 27 studies) demonstrated that QT autografts had comparable clinical and functional outcomes and graft survival rate compared with BPTB and HT autografts. However, QT autografts showed significantly less pain at the harvest site compared with BPTB autografts and had better functional outcome scores compared with HT autografts (50). Other authors investigated whether ACL-R with QT graft had a higher risk of graft failure, ACL-R revision, or reoperation compared with HT graft in a high-volume center in a registry study reviewing 475 patients (51). The rate of graft failure at 2 years was 9.4% in the QT group and 11.1% in the HT group ($P=0.46$). In the QT and HT groups, the rate of ACL-R revision was 2.3 and 1.6% ($P=0.60$), respectively, and the rate of re-surgery due to cyclops lesion was 5.0 and 2.4% ($P=0.13$). They demonstrated that QT and HT grafts yielded similar rates of graft failure, revision ACL-R, and reoperation at 2 years of follow-up after ACL-R.

Besides graft type, graft size is a predictive factor in primary ACL-R. A diameter of at least 8 mm is considered a ‘critical graft size’ to minimize the risk of graft failures and revision procedures (52, 53). This cutoff value was confirmed for ACL revision surgery by two registry studies using data from Norway, Sweden, and New Zealand (54, 55).

There are also patient-specific anatomical factors that can increase the risk of ACL-R failure. This includes a small stenotic femoral intercondylar notch that increases the risk of graft failure after ACL-R (Fig. 2). In the most severe cases especially in revision cases with big osteophytes in the notch, a notchplasty during ACL-R should be considered (56, 57); albeit there is chance of bony regrowth. Besides the notch size, the relationship between other bony morphologic characteristics such as size of the femoral condyles and the ratio between medial and lateral femoral condyle size may also influence the risk of ACL injury risk and graft failure. Differences in medial-to-lateral femoral condyle size ratio change the amount of rotation of the knee, which could potentially lead to differences in the stress placed on the ACL graft (58, 59). Despite the lack of evidence about the role of this topic in the revision ACL surgery, experts believe that anatomical risk factors should be given even greater attention in case of revision surgery. The hip impingement is an anatomical condition often associated with a predisposition to ACL rupture and thus a higher risk of failure of ACL-R. It is accompanied by limited ROM, especially during internal rotation, simulating a pivot landing on the ipsilateral knee, which therefore increases stress on the ACL (60, 61).

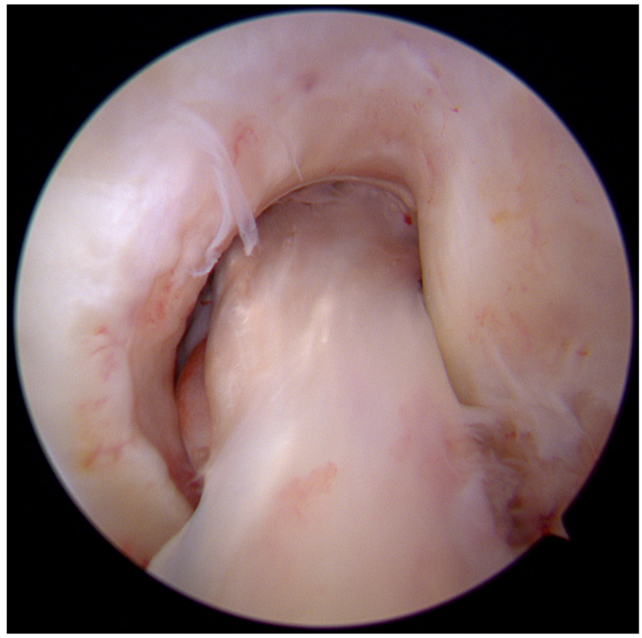

Figure 2
Stenotic, very small notch with a vertical, non-anatomical graft.

Particular attention must also be paid to patients with general joint laxity (Fig. 3) especially patients with connective tissue diseases (e.g. Marfan or Ehlers–Danlos syndrome) (62, 63, 64). Patients with increased general laxity have an increased graft failure rate and lower subjective outcome scores after ACL-R. A study comparing patients after ACL-R with and without generalized joint laxity and two different graft types (HT and BPTB) reported (i) less satisfactory stability and functional results in patients with generalized joint laxity compared to patients without generalized joint laxity and (ii) that patients with a BPTB graft achieved better results compared to patients with a HT graft (65).

Figure 3
Patient with increased general laxity.

Smokers must expect a significantly worse clinical outcome, an increase in anterior translation, and an increased complication rate after ACL-R, accompanied by lower PROMs (6, 66). Like smokers, patients with chronic inflammatory diseases are at higher risk for ACL lesion or failure of a previous ACL procedure if they have any of the above predisposing factors (67).

Septic arthritis represents an uncommon complication after ACL-R (estimated incidence of less than 1–1.8%), but which, if present, can lead to failure of primary reconstruction and very poor clinical outcomes (68, 69). Post ACL-R septic arthritis can be defined by the time of onset as acute (within the first 2 weeks), subacute (between 2 weeks and 2 months), and chronic (over 2 months). Furthermore, they can be clinically distinguished in acute or low grade, the latter being much more difficult to diagnose. In patients with clinically suspicious septic arthritis after ACL-R (calor, rubor, dolor, tumor, and poor function), laboratory tests are carried out with blood tests to study the number of leucocytes and C-reactive protein. Additionally, joint fluid aspiration is mandatory, and infection should be considered until it has been excluded. The aspirated fluid should be judged by the examiner. Number of leukocytes (cutoff: if >20 000) and the percentage of granulocytes of leukocytes (cutoff: if >90%) should be analyzed, and if positive the knee should undergo surgery (70). The aspirated fluid is also sent for microbiological analysis such as gram staining and culturing. During surgery, grafts can be mostly sustained during first surgery (at least in acute and subacute cases). During surgery, intraoperative histological and bacteriological sampling are also harvested (71). If a second surgery because of septic arthritis is necessary, one should think about a new MRI to exclude an infected Baker's cyst, which might work as a germ reservoir and thus should be removed too. The most common bacteria involved are *Staphylococcus aureus* and coagulase-negative staphylococci (72). The surgical times of greatest risk for bacterial colonization are harvesting and the preparation of the graft. The risk increases in the case of previous knee surgery or concomitant surgical procedures to ACL-R due to increased operating times and major skin incisions (72, 73). A strong reduction in the incidence of post-ACL-R infections has been demonstrated through soaking ACL grafts in a vancomycin solution before implanting (74, 75).

Early RTS is a leading cause of ACL-R failure and is about seven times higher in those exercising excessively before 9 months (76). Instead, those returning to sport after 9 months have been shown to have a lower rate of second injuries (77). Of great importance is the restoration of neuromuscular assessment to ensure muscle stability during AP translation, varus/valgus, and rotational loading (2, 52) as well as graft maturation. A recent meta-analysis has shown that also reduced psychological readiness of RTS is one of the main factors that can cause graft re-rupture after ACL-R (78). The average rate of RTS after an ACL-R at pre-injury levels varies from values below 40–52% (25). High patient compliance during the rehabilitation phase plays a very important role. Early identification of patients who exhibit some form of psychological distress, fear avoidance behavior, low perceived self-efficacy, or pessimistic personality traits may be helpful in improving preoperative risk stratification for rehabilitation or surgical planning procedure (53, 79).

History, clinical evaluation, and imaging

There is a lack of high evidence studies to determine exactly which aspects of the patient history should be documented in case of a known or a suspected failed ACL-R. History is a fundamental part of the diagnostic process of the ACL failure, including identification of its etiology and optimization of treatment planning. The following aspects of the patient's history should be documented in the setting of a known or suspected failed ACL-R: demographics, including gender, age, body mass index, smoking habits, date of previous ACL-R; surgical report, previous treatment, imaging, and associated lesions; previous failures, time of return to activity and sports, current activities of daily living (ADLs) as well as sporting activities prior to reinjury; symptoms; if a trauma occurred and if yes, which mechanism; history of septic arthritis or recent acute joint inflammation; comorbidities such as rheumatoid related diseases and Marfan syndrome; status of contralateral knee; patient expectations; and so on.

Nonmodifiable demographic characteristics have been reported to affect the failure rate of ACL-R, such as young age, especially less than 25 years. In male patients younger than 18 years, it was reported to be up to 19% (14, 80, 81). Other patient-specific characteristics, some of which are modifiable, are also thought to have an influence on ACL failure, particularly related to the type of sport and timing of RTS after ACL-R. Ninety percent of ACL failures occurred in high-risk sports (e.g. pivoting, jumping, landing, and cutting), with young female athletes being specifically at increased risk (80).

The following aspects of the physical examination should be performed and documented in the setting of a known or suspected failed ACL-R: assessment of AP and rotational laxity. AP laxity can be assessed by the Lachman test, which is superior to the anterior drawer test (78). The Lachman test can be performed manually or in an instrumented way utilizing for example the KT-2000 or the Rolimeter. To evaluate rotational laxity, several tests have been described, including the Losee test, the Jerk test, and the pivot shift test (grading, 0 – none to 4 – gross); whereby the latter one has been the most popular one. However, the reliability of the pivot shift test remains questionable, and therefore a more standardized technique has been recommended recently (67, 76, 82, 83, 84, 85). For the pivot shift test, some instrumented ways have been established to measure its magnitude. A high grading of the pivot shift test is considered as a risk factor for primary and revision ACL-R failure (86). Nevertheless, before diagnosing an ACL retear or ACL-R insufficiency, a tear of the PCL must be ruled out. Of course, the knee assessment should also include the assessment of for example collateral ligaments and menisci. Additionally, ROM must be assessed. Preoperative hyperextension of >5° has been shown to be an independent, significant predictor of graft failure after primary (87) and revision ACL-R (88). Furthermore, lower limb alignment (genu varum or valgum) (89), donor site morbidity, classical signs of arthritis (rubor, calor, swelling, pain, impaired knee function), muscle status (i.e. atrophy), and neurovascular status should be assessed.

Clinical examination can be supplemented by specific imaging. For initial imaging, x-rays (knee in AP and lateral view) can be used to rule out fractures, and the lateral view can be used to determine the tibial slope. In older patients, AP weightbearing x-rays (e.g. Rosenberg or Schuss view) can be used to exclude osteoarthritis (OA). In the rare case that clinical examination and MRI are inconclusive, stress x-rays can be performed using for example the Telos system for better quantification of side-to-side differences (90). Nowadays, in general, a native MRI (without contrast agent) is also performed to evaluate the ACL graft, tunnel size, and possible concomitant pathologies such as meniscal and cartilage lesions (91). In case an ACL-R revision is planned and bone tunnel enlargement was shown on x-rays or MRI, a CT scan might be necessary to exactly determine their size and position as x-rays and MRI are not precise enough to do so (Fig. 4) (79, 92).

Management of failure

Revision ACL-R procedure is technically more demanding than primary ACL surgery, and multiple factors in addition to ACL insufficiency must be taken into consideration (15, 65). Thus, preoperative elaboration of a surgical strategy is mandatory to be optimally prepared for revision surgery. In general, revision ACL-R is considered for any patient with subjective instability aged ≤50 years, regardless of sports activity level, meniscal status, acceptable ROM, and OA grade. However, patients with a low activity level (i.e. low points in the Tegner score) and a non-functional meniscus or high grade of OA (i.e. Kellgren & Lawrence ≥ III°) are treated rather conservatively. Nevertheless, even in patients >50 years with high sports or daily activity expectations, revision ACL-R can be indicated if the patient exhibits subjective instability, has a repairable meniscus tear, and has no OA (Kellgren & Lawrence ≥ III°) (66, 93, 94, 95, 96, 97).

Graft choice seems to play an important role in achieving better results in ACL-R, but it obviously depends on the graft already chosen for primary reconstruction. However, the surgeon must decide which graft is the most appropriate for the individual patient, in accordance with the technique he trusts (98). Potentially, all kinds of autografts and allografts can be used. A recent systematic review and meta-regression analysis, which included more than 50 000 patients, found an overall revision rate of 3.1% with a median follow-up of 2.3 years (99): HT autografts accounted for 2.7%, BPTB autografts for 2.4%, and other graft types 5.2%. They concluded that BPTB autografts had the lowest revision rate and a slightly decreasing trend in failures over the past 45 years, although both BPTB and HT autografts are reliable graft choices. A recent study compared both HT and QT autografts for revision ACL-R and found no outcome difference (100). Another work showed that there was no difference in the recovery of knee stability and function

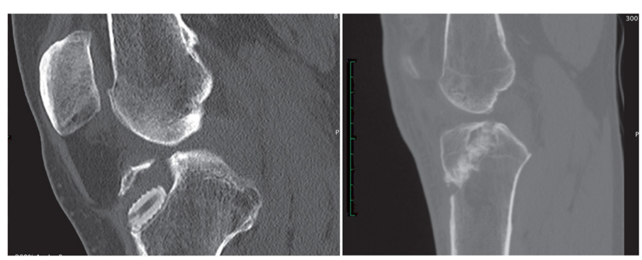

Figure 4
Left – tibial bone tunnel enlargement with screw. Right – tibial bone with allogenic bone grafts 4 moths post filling.

in revision ACL-R when a QT graft or a contralateral semitendinosus-gracilis graft was used (101). Other studies investigated on the use of BPTB autografts for revision ACL-R, with a similar outcome to primary ACL-R using the same kind of graft (102, 103). It was also demonstrated that activity function and PROMs improve when an autograft was used compared to an allograft and showed a decreased risk of graft re-rupture at a 2-year follow-up (102). A more recent systematic review showed that autografts had better results in outcome score, such as lower rates of graft retear, higher rates of RTS, and less postoperative AP knee laxity compared to allograft in ACL revision procedures (104). Several studies have dealt with the issue of graft harvesting from the contralateral knee and have shown that this method could be a valid option compared to harvesting from the affected knee in revision ACL-R (105, 106, 107). Graft choice may also be influenced by tunnel size, since a graft with a bone block may allow compensation for larger bony defects (108, 109, 110). An allograft with a large bone block can compensate for a larger bony defect, whereas soft tissue grafts cannot. Nevertheless, huge tunnel enlargements in a failed ACL are suspicious for a low-grade infection, which should be excluded first.

There are two common scenarios when bone grafting of the tunnels is necessary: (i) a previously partially non-anatomic tunnel which interferes with a new anatomic tunnel and would result in a confluent tunnel and (ii) a previously anatomic tunnel position exceeding the critical diameter, with reported values ranging between 12 and 15 mm (10). The value for a critically sized tunnel may also vary depending on graft choice, drilling technique, and fixation technique (10, 111). However, bone grafting does not necessarily have to be performed as a two-stage procedure but can also be performed concomitantly with revision ACL-R as a single-stage procedure based on several techniques (112, 113). Nevertheless, techniques like these should be reserved for experienced surgeons.

The decision to perform revision ACL-R as a single- or two-stage procedure is not just based on tunnel size and position but also on some other factors such as ROM, infection status, concomitant pathologies (i.e. limb alignment and cartilage and meniscal status), and concomitant ligamentous insufficiency (114, 115, 116). Beneath the disadvantages of a two-stage procedure (i.e. more surgical interventions, longer rehabilitation, and a prolonged period of ACL deficiency with a potential risk of secondary cartilage and meniscal injuries), a recent systematic review compared outcomes and failure rates of single- vs two-stage ACL-R. The authors found comparable clinical outcomes, lower rates of revision surgery, and clinical failure after a two-stage approach (117). Besides these works, the evidence base to date is low, and most are based on high-level expert recommendations.

Malalignment of the lower limb, with significant varus or valgus, may be considered a risk factor for ACL graft failure due to repetitive overload and stress forces on the graft (118, 119). An osteotomy to correct coronal malalignment is suggested in patients with varus or valgus deviation ≥ 5° accompanied by early OA. Further indications for osteotomy in the coronal plane include significant cartilage damage and/or symptomatic meniscal defects in patients with varus or valgus deviation associated with ligamentous insufficiency (120, 121). Furthermore, an osteotomy to correct the tibial slope might be necessary in ACL revision surgery. The assessment of the tibial slope during the preoperative evaluation is crucial to address an adequate ACL revision surgery (119, 122, 123). A steep posterior tibial slope (PTS) has been shown to be a clear risk factor for ACL-R failure and increased AP laxity (124, 125). Biomechanical studies have shown that tibial slope has a strong linear relationship with the forces acting on the graft. Thus slope-reducing osteotomies can decrease ACL graft forces (126) and should be considered in patients with failed ACL-R and steep native slope (127, 128). The indication for this procedure might even more important in patients with involvement of the posterior horn of the medial meniscus. In this case, the AP translational forces are markedly greater (77), potentiating the effect of a steep native PTS (129). Most authors suggest considering a slope-reducing osteotomy if PTS exceeds 12° on lateral knee radiographs (128, 130). An increased tibial slope is usually corrected by an anterior closing-wedge osteotomy at the proximal tibia. ROM must be taken into consideration, and postoperative hyperextension >5° should be avoided; and thus, preoperative pathological hyperextension is an exclusion factor.

Both the medial and lateral menisci act as secondary knee stabilizers (or secondary stabilizers of the ACL). It was demonstrated that meniscal deficiency is a very significant factor in predicting graft failure in single-bundle ACL-R (131). In case of significant meniscal loss, concomitant or staged meniscal transplantation – if legally and financially possible – should be considered. As already mentioned early, so far it is unclear if lesions of the meniscus ramp should be fixed. Supportive literature to do so is missing. However, untreated meniscal tears during the first ACL-R, especially root tears, may contribute to the long-term failure of primary ACL-R and to an increased risk of an early onset of OA (131). It is therefore important to adequately treat such tears during revision surgery. A tear of the posterolateral meniscus root is clinically relevant but often a missed concomitant injury in patients with an ACL tear (132). Treatment of choice is a TT repair with one or two separate bone tunnels – additionally to the tibial ACL tunnel. In patients with a high-grade pivot shift, ACL insufficiency is usually combined with other structural damage such as a posterolateral root tear and/or insufficiency of the anterolateral structures. Isolated revision ACL-R may not be able to restore normal knee kinematics, and all involved structures should be addressed.

Despite the actual lack of high-level evidence, it is strongly recommended in revision ACLR surgery to restore or improve rotatory stability of the knee with additional procedures such as lateral extra-articular tenodesis or anterolateral ligament reconstruction (ALL). These procedures, done in combination with an ACL-R, has been shown to clearly decrease the amount of primary and revision ACL-R without compromising its outcome in other areas, e.g. PROMs or early onset of OA. A systematic use of additional anterolateral procedure in revision ACL surgery should be considered in young, active patients and athletes as well as in cases with clinical signs of increased joint laxity (e.g. pivot shift +++, grade II or III IKDC (International Knee Documentation Committee) of AP instability, pivoting sports, and hyperlaxity) (133, 134, 135, 136, 137).

Conclusion

Revision surgery of failed ACL-R remains complex even for experienced surgeons. Despite advances in diagnostic and therapeutic procedures, it is crucial to always tailor therapeutic procedures to the individual patient, considering their pre-existing conditions, surgeries, lifestyle, and expectations concerning RTS or postoperative activity level. A new traumatic mechanism at the previously treated knee has been shown to be the most common cause of re-rupture, followed by technical errors, especially malposition of the femoral tunnel. These and many other causes can be crucial for the failure of a primary ACL surgery, especially when related to patient anatomical conditions that increase the risk of a re-rupture. Furthermore, adequate implementation and good timing of a rehabilitation program after ACL surgery is of great importance. Adequate preoperative planning is essential in ACL revision. Different aspects must be considered, such as the graft choice, the performance of additional procedures at the bone level, treatment of insufficient peripheral ligamentous structures, and/or possible meniscal tears and chondral defects. Here, the addition of lateral extraarticular tenodesis seems to clearly decrease ACL re-rupture rates. Another big improvement of the recent years has been the decrease of the dreaded septic arthritis by soaking the graft in a vancomycin solution.

ICMJE conflict of interest statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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