Review Article

Current development in surgical techniques, graft selection and additional procedures for anterior cruciate ligament injury: a path towards anatomic restoration and improved clinical outcomes—a narrative review

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Background and Objective: Anterior cruciate ligament (ACL) reconstruction has been widely used for ACL injury for a long time. However, residual rotational instability and osteoarthritic changes after ACL reconstruction have been identified as problems. Thus, anatomic reconstruction techniques, various types of grafts and additional procedures have been desired to improve the clinical outcomes and knee instability. Although clinical outcomes and knee stability are better than in the past, ipsilateral graft failures still occur in 4–17% and osteoarthritic changes are seen in about 20% of patients after ACL reconstruction. To remedy these problems, it is necessary to improve the understanding of various surgical techniques and grafts and to pursue further improvement of surgical techniques. Therefore, the objective of this review is to summarize the advantages and disadvantages of various surgical techniques and graft selection, and additional procedures for ACL injury.

Methods: A literature review was conducted on the surgical procedures for ACL injury. Recent trends in surgical techniques, graft selection, and additional procedures for ACL injury were described. We performed a literature search in PubMed for studies published from origin to May 8, 2023. Studies were required to be English-language articles.

Key Content and Findings: Although many reports indicate that double-bundle ACL reconstruction is comparable to anatomic single-bundle (SB) reconstruction, intraoperative complications such as tunnel coalition exist in double-bundle reconstruction, and the technique needs to be improved. ACL repair has shown good short-term results, but long-term results need to be examined in the future. Quadriceps tendon autograft is being used more frequently, but hamstrings tendon autograft and bone-patellar tendon-bone autograft also have good results. In addition, in higher-risk cases, lateral extra-articular tenodesis (LET) and anterolateral ligament (ALL) reconstruction can be performed with good results.

Conclusions: To further improve clinical outcomes, more anatomical reconstructions should be pursued. Autografts are better than allografts and synthetic grafts, but further study is needed to determine which graft is better. Additional procedures should be performed in highly unstable cases and in revision cases.

Keywords: Anterior cruciate ligament (ACL); ACL reconstruction; graft selection; lateral extra-articular tenodesis (LET); anterolateral ligament reconstruction (ALL reconstruction)

Received: 07 October 2022; Accepted: 30 July 2023; Published online: 01 September 2023.

doi: 10.21037/aoj-23-39

View this article at: https://dx.doi.org/10.21037/aoj-23-39

Introduction

Background

Anterior cruciate ligament (ACL) injuries account for about 50% of knee injuries and are commonly treated with ACL reconstructions (1). Approximately 200,000 people in the United States suffer ACL injuries annually and 120,000 people undergo ACL reconstructions and the incidence of ACL injuries was estimated between 32 and 68.6 per 100,000 (2-5).

ACL reconstruction has long been performed to prevent knee instability and subsequent meniscus damage associated with ACL injury. In the past, ACL reconstruction using transtibial (TT) drilling techniques were widely performed, but this technique failed to create the femoral and tibial tunnel in the exact position (6,7). ACL reconstruction using independent drilling technique has been used to create the tunnel in a more anatomic position, providing greater knee stability and reducing the risk of postoperative osteoarthritis (OA) than the TT technique (8-10). As a further anatomic reconstruction technique, the double-bundle (DB) ACL reconstruction was developed, which showed better knee stability (11). Moreover, surgical techniques for ACL injury are becoming more diverse, including ACL repair (12) and ACL augmentation (13).

Regarding grafts for ACL reconstruction, bone-patella tendon-bone (BTB) autografts were commonly used in ACL reconstruction, but due to concerns about anterior knee pain (14,15), hamstring tendon (HT) autografts are now more commonly used, and quadriceps tendon (QT) autografts are increasingly being used as well (16). In recent years, some institutions have used the peroneus longus tendon (PLT) autografts (17,18), considering the weakness of the muscle strength around the knee and quadriceps-hamstring imbalance (19,20). Allografts and synthetic grafts have also been used as grafts for ACL reconstruction, but the graft failure rate is high and has not improved clinical outcomes (21,22).

Although these various surgical techniques and graft selections are performed, the graft failure rate after ACL reconstruction is as high as 4–17% (23-25), and approximately 20% of patients will develop OA in the long-term follow-up after ACL reconstruction (26).

While lateral extra-articular tenodesis (LET) (27), anterolateral ligament (ALL) reconstruction (ALLR) (28) and anterior closed-wedge high tibial osteotomy (ACW-HTO) (29,30) are now being used as additional procedures in cases of high instability or high posterior tibial slope (PTS) and are expected to improve clinical outcomes (31-33), there is also a need to reconsider current surgical techniques, graft selections and additional procedures in order to improve clinical outcomes and knee stability.

Objective

In this review, we describe the advantages and disadvantages of surgical techniques, graft selections and additional procedures for ACL injury, to summarize current problems, and to improve future surgical techniques. Our hypotheses are that more anatomical reconstructions lead to better clinical outcomes. Grafts are best used with autograft, but the choice of autograft type is a matter of consideration. We present this article in accordance with the Narrative Review reporting checklist (available at https://aoj.amegroups.com/article/view/10.21037/aoj-23-39/rc).

Methods

A PubMed database search was conducted to gather studies on surgical techniques, graft selections, and additional procedures for ACL injury. The selection of articles was based on author-determined credibility, relevancy to the topic, and current trends in managing ACL injury. Specific search terms from *Table 1* were utilized, and a summary of the search strategy is provided in *Table 2*. Furthermore, additional articles were included in the review by referencing the bibliographies of previously acquired articles.

Results

Surgical techniques (Table 3)

ACL reconstruction

ACL reconstructions are performed to restore the knee stability and are essential for young patients with ACL injuries who wish to return to sports (80,81). In the early 1990s, arthroscopic ACL reconstructions were performed with 'non-anatomic' reconstruction using the TT technique to create a femoral tunnel. But in this technique the femoral tunnel is created from the tibial tunnel, the femoral tunnel is created in the 'over-the-top' position, which is a non-anatomic position (9). Improper positioning of the femoral tunnel resulted in the secondary knee osteoarthritis and clinical failures due to persistent instability (37,82,83). To create a femoral tunnel closer to the anatomical position, the anteromedial portal technique (transportal technique)

was developed and is now widely performed as an 'anatomic' reconstruction technique (36). The bone tunnel drilled through the anteromedial portal tends to be inclined more towards the lateral cortex of the lateral femoral condyle. This inclination ultimately leads to superior rotatory stabilization of the knee joint when compared to TT technique (38). Compared to the TT technique, the anteromedial portal technique has been reported to provide superior knee stability, better clinical outcomes, and a reduced risk of OA progression (10,37,39).

In recent years, the all-inside technique has been reported as a less invasive technique. This technique uses an outside-in approach to create bony tunnel in both the femur and tibia, and an adjustable suspensory device is used to fix the graft (41). This technique allows for preservation of the epiphysis, and Placella *et al.* (40) reported that ACL reconstruction using the all-inside technique was performed for ACL injuries in immature bone patients, and all patients returned to sports (average 6.4 months) and no rerupture were observed at 8 years of follow-up. However, the all-inside technique is technically difficult and requires a long learning curve. For example, the graft must keep tension in the socket and must not bottom out in the socket (41).

The over-the-top technique has also been performed as one of the ACL reconstruction techniques (84). This technique has been performed on skeletally immature patients (42) and revision cases (44), and Nagai *et al.* (45) demonstrated good anterior and rotational stability in both cases. However, in skeletally immature patients, graft failures of 12.5–25% have been reported (42,45,46), possibly due to smaller graft size in younger patients (85). Moreover, there have also been some recent reports of over-the-top techniques combined with LET (86,87). Grassi *et al.* (87) reported good patient reported outcomes with a minimum 10-year follow-up, with only 3% resulting in revision ACL reconstruction. However, this technique is a non-anatomic reconstruction and may increase stress on the graft (43).

When considering anatomic ACL reconstruction, it should be remembered that the ACL consists of two bundles, anteromedial (AM) and posterolateral (PL) bundles. Since the single-bundle (SB) ACL reconstruction can only reconstruct the AM, the PL or something similar, DB ACL reconstruction technique was developed in the search for a more anatomic restoration of the structure (57,58). In biomechanical studies, Yagi *et al.* (11) reported that anterior tibial translation of DB ACL reconstruction was closer to intact ACL than SB ACL reconstruction, and that DB ACL reconstruction showed a greater force than SB ACL reconstruction for rotatory loads. In the study using an intraoperative navigation system, Plaweski *et al.* (47) reported that DB ACL reconstruction was superior in terms

Table 1 Search terms used

Anterior cruciate ligament reconstruction
Anterior cruciate ligament repair
Anterior cruciate ligament augmentation
Autografts for anterior cruciate ligament reconstruction
Allografts for anterior cruciate ligament reconstruction
Synthetic grafts for anterior cruciate ligament reconstruction
Lateral extra-articular tenodesis
Anterolateral ligament reconstruction
Anterior closed-wedge high tibial osteotomy

Table 2 Summary of the search strategy used

Items	Specification
Date of search	10/8/2022–5/8/2023
Databases and other sources searched	PubMed
Search terms used	Please see *Table 1*
Timeframe	From origin until 5/8/2023
Inclusion and exclusion criteria	Inclusion criteria: original articles and review articles about surgical techniques, graft selections, and additional procedures of anterior cruciate ligament injury written in English
	Exclusion criteria: (I) articles not written in English, (II) case reports or studies reporting less than 10 cases
Selection process	Selection was conducted by a single author (Nukuto K)

Table 3 A summary of the surgical techniques

Surgical techniques	Pros	Cons
ACL reconstruction		
TT	–	Non-anatomic femoral tunnel position (34,35)
Transportal	Femoral tunnel position more anatomical than TT (36)	Stil high graft failure rate and osteo-arthritic changes (23-26)
	Better rotatory stability of the knee than TT (10,36-39)	The injury of the infrapatellar branch of the saphenous nerve injury (37)
All-inside	Capable of preserving the epiphysis (40)	A long learning curve (41)
	Less invasive technique (41)	Technically difficult (41)
Over-the-top	Capable of preserving the epiphysis (42)	non-anatomic reconstruction (43)
	Good knee stability in revision and skeletally immature cases (42,44,45)	High graft failure rate in younger patients (42,45,46)
Double-bundle	Better knee stability than single-bundle (11,47,48)	Long learning curve (49)
	Similar or better clinical outcomes compared to single-bundle (50-55)	High costs (56)
	More anatomical reconstruction (57,58)	Tunnel coalition (59-63)
ACL augmentation	Good indication for partial ACL tear (64-67)	Technically difficult (68)
	More graft synovial coverage and preservation of proprioceptive function (65,66,69)	Graft hypertrophy (Cyclops and ROM limitation) (13,66,67)
	Better knee stability (65,66)	
ACL repair	Good indication for acute proximal ACL tear (70,71)	A higher rerupture rate (72-74)
	Preserving proprioceptive function and more normal knee joint mechanics (75)	No long-term results with new techniques (76-79)

ACL, anterior cruciate ligament; TT, transtibial; ROM, range of motion.

of both rotatory and anteroposterior laxity. Moreover, in a meta-analysis of biomechanical comparison, Oh *et al.* (48) reported that DB ACL reconstruction was superior in terms of anteroposterior stability. In clinical studies, however, most reports indicate that DB and SB ACL reconstruction are not different in clinical outcomes (50-52), although there are some reports that DB ACL reconstruction is superior to SB ACL reconstruction in terms of postoperative rotatory and anteroposterior knee stability (53-55). In the randomized clinical trial with 10 years follow-up, Balasingam *et al.* (88) reported that there were no significant differences in the pivot-shift grade, anteroposterior stability using KT-1000 knee ligament arthrometer (KT-1000) (MEDmetric Corp., San Diego, CA, USA), a range of motion (ROM) and patients reported outcomes in 39 DB patients and 31 SB patients who were available for 10-year follow-up. In the systematic reviews, Mascarenhas *et al.* (53) reported that in DB ACL reconstructions, postoperative knee stabilities measured by the pivot-shift testing and KT-1000 were better than SB ACL reconstructions, but clinical outcomes and graft failure rates were no difference between two techniques. Alomari *et al.* reported that at short-term follow-up, DB ACL reconstructions showed better knee stability and clinical outcomes than SB ACL reconstructions, but at mid- and long- term follow-up, there were no difference in knee stability and clinical outcomes between two techniques (55).

Since there are few reports which demonstrated obvious clinical benefit of DB procedure over SB, DB ACL reconstructions are becoming less frequent due to the difficulty of the procedure (49) and high costs (56).

However, there may be some reasons why DB and SB ACL reconstructions have similar results in recent clinical research, even though some biomechanical researches have shown DB ACL reconstructions to be more stable. First, most clinical studies only evaluate knee rotatory instability

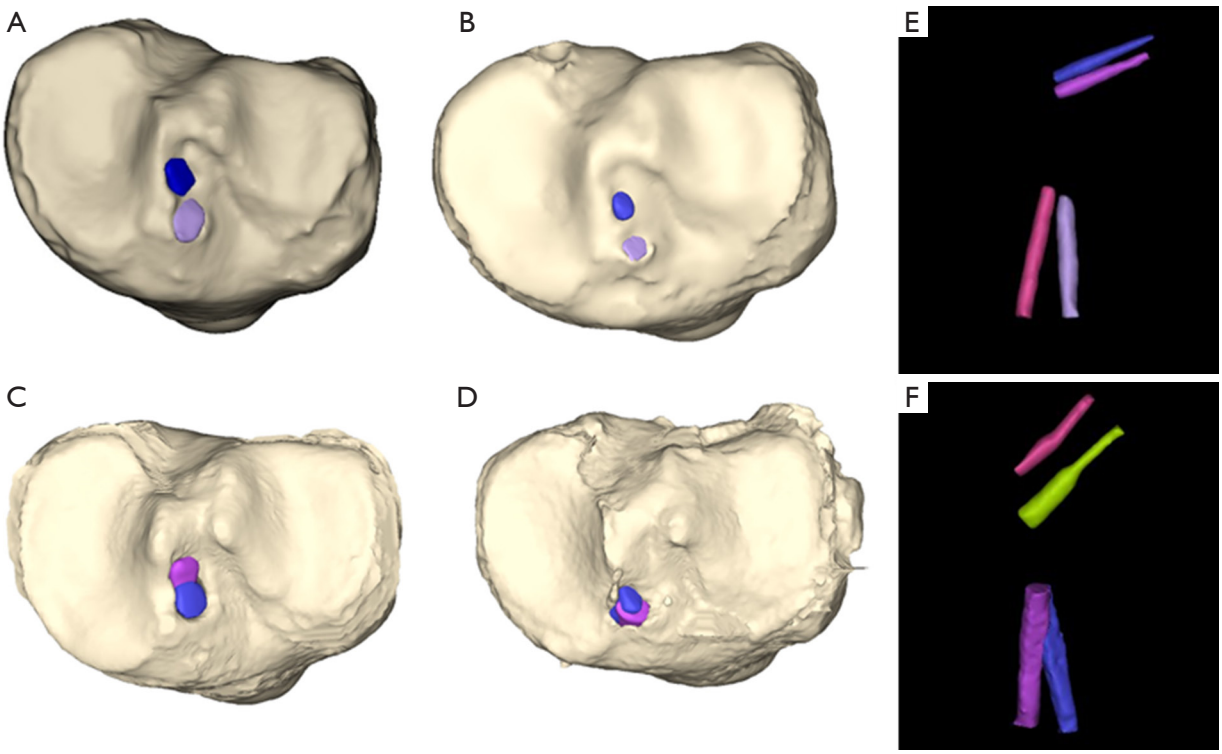

Figure 1 Tibial tunnel coalition after DB ACL reconstruction. The three-dimensional computed tomography creating by Mimics software version 24.0 (Materialise, Leuven, Belgium) shows the bony tunnel on the tibial side after DB ACL reconstruction. A and B have no tibial tunnel coalition, while C and D have tunnel coalition. E and F are extracting the bony tunnel of the tibia and femur. (F) The tunnel coalition occurs near the articular surface of the tibia. If the tunnel coalition occurs, it is not a true DB and stability may be affected. DB, double-bundle; ACL, anterior cruciate ligament.

in terms the clinical grading of the pivot-shift, which may not be an accurate assessment of stability (89-91). In a prospective randomized study comparing DB ACL reconstructions and SB ACL reconstructions, Araki *et al.* (92) reported that DB ACL reconstructions was superior to SB ACL reconstructions in terms of knee stability as assessed by electromagnetic measurement system (EMS) at 1 year postoperatively. Therefore, it is necessary to evaluate the rotatory knee stability using quantitative evaluation methods and to accumulate data in the future. Next, tunnel coalition is a common surgical complication after DB ACL reconstruction (59-61) (*Figure 1*), and it literally fails to achieve true double-bundle structure of the ACL. Femoral and tibial tunnel coalition is reported to be 0–64% and 0–77%, respectively (62), and tibial tunnel coalition influenced postoperative rotatory instability, as reported in a clinical study using EMS (63). Therefore, it would be necessary that a 'true' DB ACL reconstruction without tunnel coalition is needed to achieve a more anatomical ACL reconstruction technique.

ACL augmentation

Partial ACL tears occur in 10–35% of all ACL injuries (93) and ACL augmentation is a technique to preserve the remaining remnant of a partial ACL tear (64-67). The advantage of preserving the remnant is that blood flow is preserved, which may facilitate the graft healing process (69) and some studies reported that more synovial coverage was identified in ACL augmentation cases (65,66). In addition, proprioceptive function may be preserved, and residual ligaments may contribute to better knee stability in the early postoperative period (69). Nakamae *et al.* (65) reported that side-to-side difference in anterior translation at 1 year after surgery was better than SB reconstruction and Matsushita *et al.* (66) reported that knee stability at 1 year after PL augmentation was as good as double-bundle reconstruction. Disadvantages include procedural difficulty and graft hypertrophy. If the surgeon is experienced in the

technique, the operation time can be slightly prolonged (68), but the remnant must not be injured. In addition, if graft hypertrophy occurs, it may result in cyclops and ROM limitation (13). Although the frequency of cyclops is only a few percent (66,67), it is important to be aware of it.

ACL repair

ACL repair had hardly been performed since 1976, when Feagin *et al*. (94) published the 5-year postoperative outcomes of open ACL repair and found that reinjury after ACL repair occurred in 17 of 32 patients and postoperative instability was indicated by 94%. Since then, ACL reconstruction has become the gold standard of surgical treatment for ACL injury. However, ACL reconstruction also has problems such as pain at the graft harvest site (95), muscle weakness (96), anterior knee pain (15), and osteoarthritic change after surgery (26). So, arthroscopic ACL repair again has attracted more attention. ACL repair can preserve the native ACL's insertion site, thus preserving proprioceptive function and more normal knee joint mechanics and potentially reducing the incidence of postoperative OA (75). In addition, ACL repair has been reported to have no complications related to graft harvesting (97) and faster postoperative functional recovery (81). While recent ACL repair has reported good short-term results (12,98,99), a higher rerupture rate than ACL reconstruction has been also reported (72-74). Achtnich *et al.* (72) reported that at a mean follow-up of 28 months, ACL repair for acute proximal ACL tears resulted in rerupture in 3/20 (15%) patients, Osti *et al.* (73) reported that at the 12-month follow-up, primary ACL repair with dynamic intraligamentary stabilization (DIS) resulted in rerupture in 10/57 patients. A young age, a high Tegner score prior to injury and midsubstance tears were identified as risk factors for rerupture after ACL repair (12,99,100). The arterial blood supply to the ACL was more plentiful proximally than centrally or distally (70) and that vascularity was increased in a torn ACL compared to an intact ACL (71). So, from an anatomical point of view, proximal ACL tear seems to be a good indication for ACL repair. Moreover, there are no reports of ACL repair performed at longer intervals after injury, but some recent studies have reported good short-term results with ACL repair performed from 13 days to 2 months after injury (12,98,99), so, ACL repair may be indicated for acute ACL injury.

There are a variety of ACL repair techniques currently being performed, including DIS (76), internal brace ligament augmentation (77), suture anchor primary repair (SAPR) (78), and bridge-enhanced ACL repair (BEAR) (79), each with good short-term results, but ACL repair should be performed in a targeted manner because of the risk of rerupture.

Graft selection (Table 4)

Autograft

HT, BTB, and QT are the most commonly used as autografts for ACL reconstruction, but the gold standard of the graft source still does not exist. Until around 2008, BTB was most frequently used, but HT has gained in popularity since then, accounting for about half of the total in 2020. QT has recently increased since around 2014, and it is currently about 10% of the total (16).

BTB and HT have been reported to have a low graft failure rate (BTB: 2.0–7.0%, HT: 2.5–9.0%) (95,101-103) and similar good clinical outcomes (14,15,101). However, about BTB, anterior knee pain and kneeling pain (14,15), and long-term degenerative change have been reported (15,108). In addition, contralateral ACL ruptures were reported to be more likely than in HT (104). Regarding HT, biomechanical studies showed HT had greater mechanical properties in tensile road, stiffness, and cross-sectional area than BTB or QT (81,105). Meanwhile, some studies have reported that HT was associated with an extension loss (104-106), a higher incidence of deep infections than BTB (107), and an increased laxity over time (15).

QT has been increasing its popularity over the last ten years. The graft failure rate of QT has been reported to be 2.1–4.1%, which is similar to that of HT and BTB (95,109,110). Regarding donor site morbidity such as anterior knee pain, kneeling pain, tenderness and numbness, QT has been reported in recent years to be superior to HT and BTB (95,109,112). In systematic reviews and meta-analyses, clinical outcomes of ACL reconstruction using QT were reported to be similar to those of HT and BTB (95,109), and Brinkman *et al.* (113) reported that there was no difference in 5-year patient reported outcomes between QT and HT. Furthermore, Cavaignac *et al.* (124) reported that QT was better than HT in terms of the International Knee Documentation Committee (IKDC) subjective score and the Lysholm score at 3.6 years of follow-up. But some reports of ACL reconstruction using QT showed increased laxity than HT at 24 months postoperatively (125) and lower knee extensor strength at 12 months postoperatively than HT (111), so continued research on the selection of

Table 4 A summary of the graft selection

Graft type	Pros	Cons
HT autograft	Low graft failure rate (2.5–9.0%) (95,101-103)	Extension loss (104-106)
	Good clinical outcomes (14,15,101)	Higher incidence of deep infections than BTB (107)
	Greater mechanical properties in tensile road, stiffness, and cross-sectional area than BTB (81,105)	Increased laxity over time (15)
BTB autograft	Low graft failure rate (2.0–7.0%) (95,101-103)	Anterior knee pain and kneeling pain (14,15)
	Good clinical outcomes (14,15,101)	Long-term degenerative change (15,108)
		Contralateral ACL ruptures more likely than in HT (104)
QT autograft	Low graft failure rate (2.1–4.1%) (95,109,110)	Lower knee extensor strength than HT (111)
	Superior to HT and BTB in terms of donor site morbidity (95,109,112)	
	Similar clinical outcomes to HT and BTB (95,109,113)	
PLT autograft	High muscle strength (114-116)	A risk of the superficial peroneal nerve (17)
	Similar clinical outcomes to HT (18)	Potential for decreased clinical outcomes around the foot and ankle (18)
	Possible to preserve muscle strength around the knee (18)	
Allograft	No donor site morbidity (117)	Higher revision and graft failure rate in young patients (21)
	Graft failure rates as same as autograft over age 40 (118)	
Synthetic graft	Good short-term functional outcomes (34,35)	High graft rupture rate at long-term follow-up (119,120)
	No donor site morbidity (34,35)	Possibility of synovitis and osteoarthritic changes (121-123)

HT, hamstrings tendon; BTB, bone-patellar tendon-bone; QT, quadriceps tendon; PLT, peroneus longus tendon; ACL, anterior cruciate ligament.

tendon grafts is required.

In recent years, PLT has also been used. Biomechanical studies have reported that it has as much tensile strength as a four-strand HT (114) and that its ultimate tensile strength is approximately equal to that of the native ACL (115,116). In a systematic review, He *et al.* (18) reported that PLT showed comparable functional outcomes and knee stability compared to HT, with no significant difference in donor site pain. However, the American Orthopaedic Foot and Ankle Society (AOFAS) score, which indicates the clinical outcome of the foot and ankle, is lower than preoperatively (18), and there is a risk of injury to the superficial peroneal nerve during graft harvesting (17), so further research is needed regarding preservation of foot function.

Allograft

Among the allograft options for ACL reconstruction are HT, QT, BTB, tibialis anterior, tibialis posterior, and Achilles tendon (81). It has been reported that allografts are associated with more revisions and graft failures (117,126), and Zhao *et al.* (21) reported that the failure rate of allografts is 2.63 times higher than that of autografts. However, Kaeding *et al.* (118) reported that the difference between allograft and autograft failure rates decreases with increasing age, with only a 2% difference in the 40-year-old patients. Therefore, in areas where allografts are available, allografts may be considered for patients older than 40 years.

Synthetic graft

Since the 1980s, many arthroscopic ACL reconstructions using synthetic grafts have been performed, but the long-term results have been poor, with high rates of graft failures, synovitis, and osteoarthritic changes (121-123). In recent years, the Ligament Advanced Reinforcement System (LARS; Surgical Implants and Devices, Arc-sur-Tille, France) has been used in ACL reconstruction (127). Favorable functional outcomes and low graft failure rates in the short-term follow-up have been reported (34,35). Nau *et al.* (34) reported that any of the subscales of

Table 5 A summary of the additional procedures

Additional procedures	Pros	Cons
Anterolateral ligament reconstruction	Good clinical outcomes and low graft rupture rate for high-grade pivot shift patients (32,128-131)	The presence of ALL is not clear (132)
		Non-anatomic reconstructive procedure (133)
Lateral extra-articular tenodesis	Good indication for high-grade pivot shift or revision cases (31,134)	The possibility of lateral osteoarthritis (135)
	No graft harvesting required for LET (134)	
Anterior closed-wedge high tibial osteotomy	Good indication for high posterior tibial slope and revision ACL reconstruction cases (29,30,136)	Some complications of osteotomy (delayed un-ion, pseudoarthrosis, infection) (137)

ALL, anterolateral ligament; LET, lateral extra-articular tenodesis; ACL, anterior cruciate ligament.

Knee Injury and Osteoarthritis Outcome Score (KOOS) and Tegner score at 2 years postoperatively were not significantly different between LARS and BTB autograft. Gao *et al.* (35) reported that ACL reconstruction using LARS with a mean follow-up of 50 months showed graft failures in only 3/159 patients and residual grade 2 pivot-shift in 4 patients. While Jia *et al.* reported a graft failure rate of 4.4% at 7 years postoperatively, many reports showed high graft failure rates (31–39%) at middle and long-term follow-up (119,120). Therefore, the synthetic graft should not be selected as the first-choice graft to be used.

Additional procedures (Table 5)

Additional procedures may be considered for gross rotatory knee laxity or revision ACL reconstruction cases. The main additional techniques for soft tissues are ALLR (28) and LET (27).

ALL is described as a secondary stabilizer for anterior tibial translation and internal rotation, especially at 30°–90° of knee flexion (138,139), and Segond fracture is considered as an avulsion fracture on the tibial attachment of ALL (140,141). A lot of good clinical results have been reported for ALLR (32,128-131). Hamido *et al.* (131) reported that in male athletes with high-grade pivot shifts, combined ACL reconstruction and ALLR had a lower graft rupture rate and a better postoperative IKDC score. Sonnery-Cottet *et al.* (32) reported a better long-term ACL graft rupture rate and a lower overall rate of reoperation of combined ACL reconstruction and ALLR at 9 years postoperatively. But, on the other hand, the presence of ALL is not yet clear as a distinct ligamentous structure. Guenther *et al.* (132) reported that ALL is not a traditional ligament, but part of the anterolateral capsule, like a sheet of tissue. Herbst *et al.* (133) reported that the anterolateral complex is composed of the iliotibial band and the anterolateral joint capsule. Since ALLR may be a non-anatomical reconstructive procedure, it should be performed with caution.

Regarding LET, cadaver studies have reported that combined ACL reconstruction and LET is more effective in controlling rotatory knee laxity than isolated ACL reconstruction in cases of anterolateral complex injuries (141,142). Some good results in clinical studies have also been reported for LET. Getgood *et al.* (31) reported that for young patients with ACL injuries of pivot grade 2 or higher and younger than 25 years, combined ACL reconstruction and LET had a lower graft rupture rate and a lower clinical failure rate than isolated ACL reconstruction. According to a meta-analysis which was performed by Park *et al.* (134) combined ACL reconstruction and LET had better IKDC and Lysholm scores and a lower graft failure rate than isolated ACL reconstruction. Although the possibility of postoperative lateral OA has been reported due to overconstraint of the lateral compartment after LET (135), Declercq *et al.* (143) reported that the risk of postoperative lateral OA is not increased. So, further research is needed on this complication.

Recently, bony morphology has been reported as a factor to influence ACL injury and residual rotational instability after ACL reconstruction (144,145). The high PTS has particularly gained attention because tension on the ACL during weightbearing increased in the high PTS, and stability would be impaired after ACL reconstruction (146). Therefore, ACW-HTO has been increasingly performed recently to decrease the posterior slope (29,30,33). Some researcher reported that ACW-HTO should be considered if PTS is greater than 12° (29,30,136). Because of various complications of osteotomy, such as delayed union, pseudoarthrosis, and infection, some reports suggest that

ACW-HTO should be selectively performed, for example, in revision ACL reconstruction (137).

Strengths and limitations

Strength is that no review article has combined the surgical techniques of ACL reconstruction, ACL repair, and ACL augmentation into a single surgical procedure for ACL injuries, and this review article covers all the important surgical techniques and graft selections for ACL injuries in recent years. This article will be of particular interest to young surgeons. The limitation is that this article is not a systematic review and does not cover all previous papers related to the topic. However, this article clearly describes the advantages and disadvantages of each technique, grafts and additional procedures, so the issues to be aware of in actual surgical preparations can be well understood in this article.

Conclusions

Anatomic ACL reconstruction guarantees good clinical results. Previous DB ACL reconstructions have been failed to demonstrate obvious advantage over anatomic SB, while most of them might not have been successful in restoring double bundle structure due to tunnel coalition. ACL repair has shown good results in recent years, and long-term results are expected in the future. Allografts and synthetic grafts have a high graft failure rate, and autografts should be the first choice, but further study is needed to determine which autograft is best. There may be cases that require additional procedures such as LET or ALLR, but we should first get down to anatomic ACL reconstruction.

Acknowledgments

Funding: None.

Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://aoj.amegroups.com/article/view/10.21037/aoj-23-39/rc

Peer Review File: Available at https://aoj.amegroups.com/article/view/10.21037/aoj-23-39/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://aoj.amegroups.com/article/view/10.21037/aoj-23-39/coif). YH serves as an unpaid editorial board member of *Annals of Joint* from December 2022 to November 2024. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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doi: 10.21037/aoj-23-39
Cite this article as: Nukuto K, Hoshino Y, Kataoka K, Kuroda R. Current development in surgical techniques, graft selection and additional procedures for anterior cruciate ligament injury: a path towards anatomic restoration and improved clinical outcomes—a narrative review. Ann Joint 2023;8:39.