*Burns & Trauma*, 2025, **13**, tkae079
https://doi.org/10.1093/burnst/tkae079
**Guideline**

# Primary repair of proximal anterior cruciate ligament injury: a global expert consensus statement

**Shurong Zhang[1,‡], Tian Xia[1,‡], Xuesong Dai[2], Gregory S. DiFelice[3], Lars Engebretsen[4], Alberto Gobbi[5], Christiaan H. Heusdens[6], Gordon M. MacKay[7], Bertrand Sonnery-cottet[8], Jelle P. van der List[9,10], Shu-Hang P. Yung[11,*], Jianquan Wang[12,*], Yinghui Hua[1,*]**

[1]Department of Sports Medicine, Huashan Hospital, Fudan University, No 12, Wulumuqi Zhong Road, Shanghai, China
[2]Second Affiliated Hospital of Zhejiang University, No 88, Jiefang Road, Hangzhou, Zhejiang, China
[3]Orthopaedic Trauma Service, Department of Orthopaedic Surgery, Hospital for Special Surgery, NewYork-Presbyterian, Weill Medical College of Cornell University, New York, NY 10021, United States
[4]Department of Orthopedic Surgery, Oslo University Hospital, Oslo 3143244, Norway
[5]O.A.S.I. Bioresearch Foundation Gobbi N.P.O, Via Amadeo GA 24, I-20133, Milan, Italy
[6]Department of Orthopaedics, Antwerp University Hospital and ASTARC, University of Antwerp, Antwerp 2803138, Edegem, Belgium
[7]Stirling University, Stirling 2636910, Scotland, United Kingdom
[8]Centre orthopédique Santy, FIFA medical Center of excellence, hôpital Mermoz, groupe Ramsay, 24 Ave Paul Santy, F-69008 Lyon, France
[9]Department of Orthopaedic Surgery and Sports Medicine, The Ohio State University Wexner Medical Center, Columbus, Ohio, United States
[10]Sports Medicine Research Institute, The Ohio State University Wexner Medical Center, Columbus, Ohio, United States
[11]Department of Orthopaedics & Traumatology, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong 999077, China
[12]Department of Sports Medicine, Peking University Third Hospital, Beijing 100191, China

*Corresponding author. Department of Sports Medicine, Huashan Hospital, Fudan University, No 12, Wulumuqi Zhong Road, Shanghai 200040, China. E-mail: hua_cosm@aliyun.com; Department of Sports Medicine, Peking University Third Hospital, Beijing 100191, China. E-mail: wjqsportsmed@163.com; Department of Orthopaedics & Traumatology, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong 999077, China. E-mail: patrickyung@cuhk.edu.hk

‡Shurong Zhang and Tian Xia contributed equally to the manuscript as co-first authors.

## Abstract

The application of primary repair for anterior cruciate ligament (ACL) injuries remains controversial, and evidence-based guidelines have not yet been established. Remarkable advancements in arthroscopic techniques and biological stimuli have been achieved in the past decades, which may change expectations regarding the potential of ACL healing and clinical outcomes for patients. In this study, a global expert consensus on the primary repair of proximal ACL injuries was established. A panel of 16 experts from the fields of sports medicine and arthroscopic surgery was invited to participate in the compilation of this consensus statement. This project followed the Delphi approach to the consensus process involving steering, rating, and peer review groups. Ultimately, 14 statements were retained: four achieved unanimous support, six achieved strong consensus, and four did not achieve consensus. The expert consensus statement established in this study focused on surgical indications, decision-making, surgical techniques, adjunctive methods, prognostic factors, and rehabilitation following ACL repair. The accepted recommendations in these areas will assist doctors and therapists in standardizing the management of related pathologies. The consensus statement clearly states that the tear site and tissue quality are important for ensuring successful ACL repair, while other factors should also be considered. ACL reconstruction remains the gold standard for ACL repair until long-term follow-up data demonstrates otherwise.

**Keywords:** Anterior cruciate ligament; Primary repair; Expert consensus

### Highlights

- This expert consensus provides a global perspective on the primary repair of proximal anterior cruciate ligament (ACL) injuries, addressing surgical indications, decision-making processes, techniques, adjunctive methods, prognostic factors, and rehabilitation. It offers standardized recommendations for clinicians, which aim to enhance the management of ACL injuries.
- This consensus notes a resurgence of interest in ACL primary repair techniques due to advancements in arthroscopic procedures and biological augmentation methods. These techniques offer the potential for faster recovery and lower surgical morbidity compared to traditional ACL reconstruction, especially in specific patient groups such as those with proximal tears.
- The success of ACL primary repair heavily depends on tear location (especially proximal tears) and the quality of the remnant tissue. These factors are critical for surgical decision-making and can determine the likelihood of achieving favorable long-term outcomes compared to ACL reconstruction.

## Background

Primary repair of the anterior cruciate ligament (ACL) became popular in the 1970s and the 1980s. [1] Owing to a reported failure rate of up to 50% at 5-year follow-up [2], ACL reconstruction replaced ACL primary repair and became the main treatment option for ACL tear [3].

The results of ACL reconstruction are good; however, current techniques pose some challenges and potential issues [4, 5]. ACL reconstruction is less favorable in the case of partial tears of the ACL and in skeletally immature patients because of the complete removal of the ACL remnant or potential damage to the epiphyseal. Furthermore, it is associated with graft donor site morbidity and pain in the direct postoperative

**Received:** July 12, 2024. **Revised:** November 25, 2024

phase [6]. However, Taylor *et al*. [7] noted that despite the historically poor outcomes of *in situ* ACL primary repair over the past decade, successful outcomes in a subset of patients have been recorded. Therefore, it is worth understanding that this paradigm shift was complicated by other factors, such as heterogeneity in the patient cohort, age range, rehabilitation, surgical type, and insufficient identification of the tear pattern and location [8, 9].

It was commonly thought that the primary healing potential of the ACL was poor owing to biomechanical forces, poor blood supply, synovial fluids, and intrinsic cellular reparative properties [10, 11]. Recently, our understanding of the vascular and neural distribution, and proprioceptors of the ACL has advanced considerably [12, 13]. The interest in ACL primary repair has increased following the use of arthroscopy and the application of new tools and implants. Four main ACL repair techniques have been developed to improve the mechanical environment: bridge-enhanced ACL repair (BEAR) [14], dynamic intraligamentary stabilization (DIS) [15], internal brace ligament augmentation (IBLA) [16, 17], and suture anchor repair (SAR) [18]. Furthermore, the technique of using bioactive scaffolds to bridge the gap between the torn ligament endo casts hope for ACL primary repair [19]. Intrinsically, ACL primary repair is less invasive than ACL reconstruction as it does not require graft harvesting and requires smaller bone tunnel size [19–22]. Efforts have been made to educate patients on the indications and surgical techniques for ACL primary repair to improve treatment outcomes by preserving the biological activity of the ACL remnant tissue.

However, there is still a lack of agreement on the indications, surgical techniques, and treatment outcomes of this surgery. Therefore, it is necessary to reach an expert consensus on this issue to provide guidance for clinical practice.

## Methods

The consensus in this study focused on the clinical practice of primary repair of ACL injuries, including the clinical diagnosis, indications, ACL repair with augmentation, prognostic factors, and post-operative rehabilitation. The study was launched on 26 January and ended on 10 December 2023. This study was registered in the International Practice Guideline Registration for Transparency (PREPARE-2022CN806) platform. The selection of the consensus panel was based on clinical research publications and their impact factor in the field of primary ACL repair. The selection criteria for domestic Chinese experts for the panel were as follows: surgeons in the main clinical branch of knee sports injuries, >10 years of experience in knee ligament surgery, and performed >20 cases of ACL repair in the past 5 years.

A consensus was reached using the Delphi method. The consensus panel comprised 18 experts: a steering group ($n$ = 3), evidence rating group ($n$ = 2), a rating group ($n$ = 12), and a peer review group ($n$ = 3). The steering group proposed statements based on a systematic literature review using the PubMed, Embase, and Cochrane Central Register of Controlled Trials databases. Animal and cadaveric studies were excluded. Statements were drafted to address the current controversies regarding primary repair of ACL, including indications, techniques, and outcomes. The levels of evidence cited in the references were then classified into evidence rating groups (Table 1). Each statement and evidence was discussed within the steering group according to scientific grading before being sent for ratings.

Table 1. Grading of the levels of evidence from clinical studies.

| | |
|---|---|
| A1 | Multiple (≥2) level 1 evidence randomized controlled trials with similar findings or 1 meta-analysis |
| A2 | One level 1 evidence randomized controlled trial |
| B1 | Prospective cohort study |
| B2 | Comparison between groups but not a level 1 randomized controlled trial |
| C | Case series |
| D | Case report |
| E | Expert opinion/basic research |

In the rating process, each member of the rating group was asked to rate the statements anonymously based on scientific evidence and their clinical experience on a 5-point Likert scale ranging from strongly agree, agree, undecided, and disagree to strongly disagree. The participants were asked to provide their comments for each statement. A statement with 80% agreement or higher was defined a priori. When divergent opinions were proposed and supported, the content was revised accordingly. If the proportion of agreement votes was 50% or lower, the statement was dropped. If the proportion of favorable votes was between 50 and 80%, then the statement with its feedback was returned to the steering group for revision, and the revised draft was prepared and resubmitted to the rating group for final scoring [23].

Finally, the draft was sent to the review group for evaluation. The feasibility, accessibility, and readability of the proposed statements are shown in Figure 1.

## Clinical questions and recommendations

The demographic information pertaining to the rating group members is listed in Table 2. The steering group drafted 18 statements addressing various aspects of primary repair of ACL injuries that were sent to the rating group for two rounds of rating. During the second round of rating, one doctor withdrew from the study owing to a conflict of interest. Following discussion and review, four statements were excluded during the first round of voting because they were redundant. Finally, 14 statements were evaluated, of which four achieved unanimous support, six reached strong consensus, and four did not achieve consensus (Table 3).

***"Statement 1: ACL repair has the advantage of preserving the native ACL tissue and restoring the native femoral footprint, which may reduce surgical morbidity and time to recovery."*** **Agree: 100%.**

Modern arthroscopic surgical instrumentation has made ACL tissue repair easier, and advancements in functional tissue engineering and regenerative medicine have resulted in the revival of ACL repair. Theoretically, ACL repair is less invasive than ACL reconstruction as it does not require graft harvesting and needs smaller bone tunnel [19–22]. Thus, it has the potential benefits of retaining the native anatomy with proprioceptive fibers and avoiding the risk of donor site morbidity during graft harvest [24].

Quadriceps deficits, limited range of motion (ROM) recovery, and increased posterior pain are major concerns associated with ACL reconstruction [25–27]. Previous studies have shown that weakness of the quadriceps at three months post-ACL reconstruction has been directly linked to the development of patient dysfunction [28, 29], knee osteoarthritis (OA)

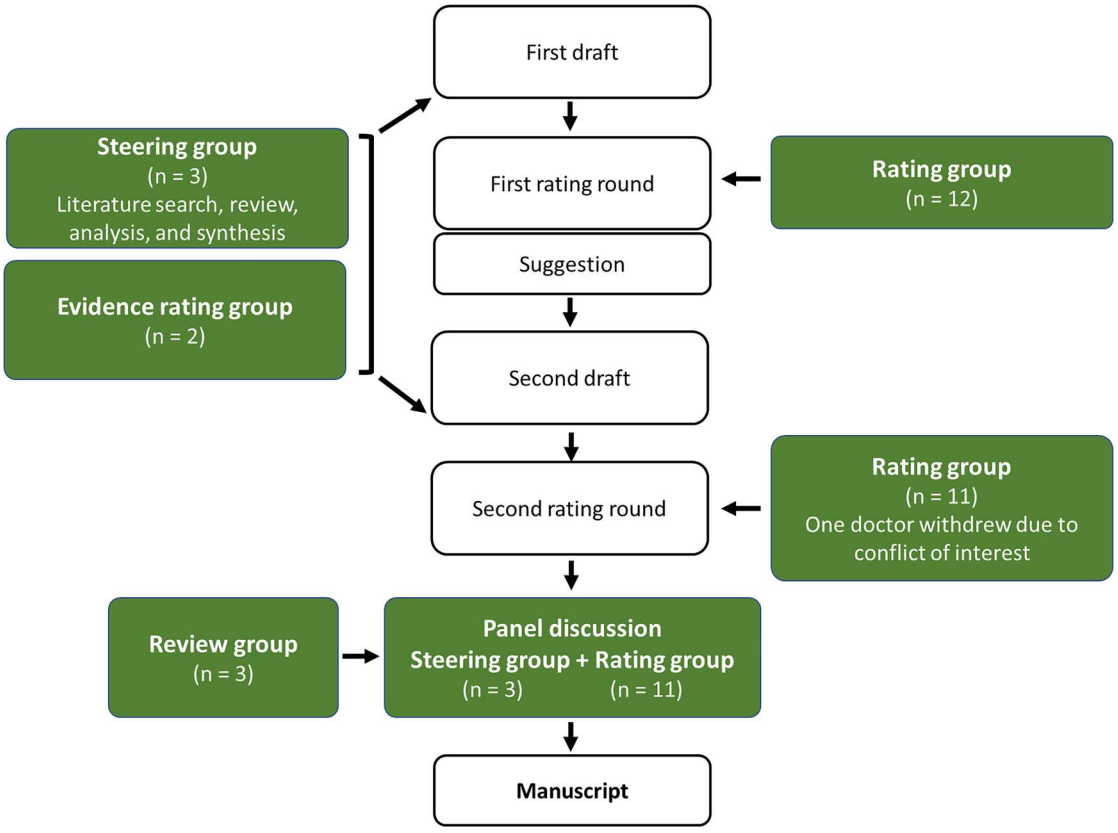


Figure 1. A schematic diagram of the steps of the Delphi method applied in this study

Table 2. Demographic information of the rating group experts

| | North America | Europe | East Asia |
|---|---|---|---|
| Region, (*n*) | 1 | 7 | 4 |
| | <50 | 50–100 | >100 |
| Case/year, (*n*) | 7 | 1 | 4 |
| | Doctor | Scientist | |
| Profession, (*n*) | 11 | 1 | |
| | Private hospital | Teaching hospital | |
| Position, (*n*) | 5 | 7 | |
| | <40 yo | 40–60 yo | >60 yo |
| Age, (*n*) | 2 | 7 | 3 |

Yo, years old.

[30, 31], and a lower likelihood of returning to the same level of sports [32, 33]. The ACL repair group experienced less postoperative pain during the first 2 weeks after surgery and used significantly fewer opioids than the ACL reconstruction group [34].

Though some studies have also claimed that at 1–2-year follow-up, comparable knee function was found following ACL repair and ACL reconstruction [19, 35–40], there is also some evidence to be concerned that these benefits come at the cost of a higher failure rate. Migliorini *et al*. reported in a systematic review that ACL reconstruction yielded greater joint stability and a lower rate of failure than surgical repair [41]. In addition, Hoogeslag *et al*. reported the 5-year results of a randomized controlled clinical trial [42], stating that it remained inconclusive whether the effectiveness of ACL repair was non-inferior to that of all-inside single-bundle ACL reconstruction in terms of subjective patient-reported outcomes. Notably, the graft failure rate of all-inside single-bundle ACL was higher than that of the standard method [43].

(Evidence Grade: B2)

***"Statement 2: The clinical indications of ACL repair include patients who have acute proximal tear, knee laxity on physical examination, and wish to return to pivot shift activities."*** **Agree: 72.73%.**

In their pivotal 1991 study on ACL repair, Sherman *et al*. categorized ACL tears into four distinct types based on the location and extent of the tear [44], noting that outcomes of repair vary with the type of tear, particularly highlighting that mid-substance tears often fail to heal due to poor tissue quality, whereas proximal tears show better repair outcomes [45–47]. By 2016, van der List and DiFelice expanded this classification to five types, identifying types I and II as most amenable to successful repair [48], backed by literature that supported excellent outcomes for primary repair of proximal

Table 3. Consensus statements on primary repair of ACL injury

| No. | Statements | Agreement (%) |
|---|---|---|
| 1 | ACL repair has the advantage of preserving the native ACL tissue and restoring the native femoral footprint, which may reduce surgical morbidity and time to recovery. | *100* |
| 2 | The clinical indications of ACL repair include patients who have acute proximal tear, knee laxity on physical examination, and wish to return to pivot shift activities. | *72.73* |
| 3 | MRI is useful to confirm the tear type before the surgery. However, arthroscopic evaluation of the ACL injury is crucial in the decision-making process. | *100* |
| 4 | In patients who do not require pivot shift activities, age, concomitant injury, and knee stability should be taken into consideration for the decision making of ACL repair versus non-operative treatment. | *81.82* |
| 5 | In the skeletally immature population, primary ACL repair is less invasive and has less disturbance to the growth plates comparing with ACL reconstruction. However, owing to the high rate of graft failure reported in this population, and it should not be the gold standard. | *81.82* |
| 6 | ACL repair needs to be performed in the acute phase. Following failed rehabilitation, ACL reconstruction is the optimal choice. | *72.73* |
| 7 | When suitable cases are selected, ACL repair including internal brace augmentation can improve the mechanical environment of the ACL tear. | *54.55* |
| 8 | ACL repair together with an anterolateral extra-articular procedure may reduce the re-rupture rate, but evidence is inconclusive. | *90.91* |
| 9 | In the case of good indication, ACL primary repair can achieve equivalent clinical outcomes as ACL reconstruction in the medium- to long-term among the active patients wishing to return to jumping, cutting, and pivoting sports. | *81.82* |
| 10 | There is limited evidence to support that biological augmentation can improve tissue healing in ACL repair. | *90.91* |
| 11 | High-quality evidence and long-term outcome analyses are required on the post-traumatic osteoarthritis (PTOA) following ACL repair. | *90.91* |
| 12 | Age, activity level, interval from injury-to-surgery, and ACL tear pattern are risk factors that should be considered when performing ACL repair. | *100* |
| 13 | Patient selection is critical and key for the success of the technique. ACL repairs are best indicated for patients with an acute, proximal ACL injury with good quality ligament remnants. | *100* |
| 14 | Postoperative rehabilitation protocol of ACL repair is similar to that of ACL reconstruction and advances more quickly depending on the individual. | *64.63* |

ACL tears, emphasizing knee stability, patient satisfaction, and return to sports [46, 49–53].

The timing of ACL repair, especially in the context of acute versus chronic phase injuries, remains debated, with evidence suggesting that tissue quality and the timing of surgery play significant roles in the success of the repair [9, 54].

The ACL Treatment Consensus Group advocates for operative treatment for active individuals aiming to return to high-demand sports, indicating ACL reconstruction as the preferred method over repair, particularly in young athletes or those participating in pivoting sports [55]. This consensus underscores the importance of considering tear location, tissue quality, and the patient's activity level in deciding between ACL repair and reconstruction, noting the limited efficacy of repair in certain populations [56] and the underexplored territory of arthroscopic repair in high-level athletes.

(Evidence Grade: B2)

***"Statement 3: MRI is useful to confirm the tear type before the surgery. However, arthroscopic evaluation of the ACL injury is crucial in the decision-making process."***

**Agree: 100%.**

The widespread adoption of MRI technology, coming after the shift towards ACL reconstruction for treating all types of ACL tears [57, 58], has opened up new avenues for preoperative assessment of ACL injuries [59]. Modern MRI techniques allow for detailed visualization of the ACL's anatomical course, aiding in the pre-surgery evaluation of tear location and tissue quality [60–62]. Good tissue quality is defined as the distal ACL presenting a homogeneous low signal on sagittal proton density-weighted images of MRI, whereas poor quality is defined as distal ACL presenting heterogeneous signal with fibers running in different directions [63]. Van der List *et al*. demonstrated that MRI could predict the suitability for arthroscopic primary repair of proximal ACL tears with high accuracy, finding that 93% of patients with type I or II tears and good tissue quality were candidates for repair [64]. However, MRI is not infallible; accurately identifying the specific nature of ACL disruptions, especially in the acute phase, remains a challenge [65], and the imaging findings do not always correlate directly with the functional status or stability of the knee [66, 67].

Despite the advancements in imaging, the ultimate decision on whether to proceed with ACL repair or reconstruction is often made during arthroscopic examination. Moura *et al*. proposed an evaluation technique to assess the feasibility of ACL repair by examining the reducibility of the ACL remnant to the femoral wall in different knee positions. This approach allows surgeons to directly assess the condition of both the anteromedial and posterolateral bundles of the ACL. ACL repair can be performed if the remnant is reducible; otherwise, ACL reconstruction is appropriate [68].

(Evidence Grade: C)

***"Statement 4: In patients who do not require pivot shift activities, age, concomitant injury, and knee stability should be taken into consideration for the decision making of ACL repair versus non-operative treatment."***

**Agree: 81.82%.**

For individuals engaging primarily in non-pivoting activities, which place less strain on the knee's ligamentous stabilizers, maintaining anteroposterior stability through muscular control rather than surgical intervention is a viable approach [69]. This is particularly true for those considered low-demand patients, where conservative treatment and rehabilitation, guided by a skilled physiotherapist, present a valuable alternative. Emerging evidence suggested that ruptured ACL may spontaneously heal after conservative

treatment and satisfactory functional results have been observed [12, 70, 71]. This healing tends to occur in low-demand patients with femoral single-bundle lesions without an increased posterior tibial slope [71, 72], though it remains uncertain which factors predict ACL healing. Despite some evidence of good short- to mid-term outcomes in knee function and performance after conservative treatment, there's a notable reduction in activity levels post-injury, and the long-term functionality of a healed ACL remains a matter of debate [73].

The choice between conservative management and surgical intervention for ACL injuries involves a complex decision-making process that should ideally be collaborative, taking into account the patient's specific situation, preferences, and the nuanced evidence available [55]. Factors such as age, desired sports and work activities, intensity of sporting activities, and associated lesions may inform patients and practitioners about the possibility of non-operative management. The lack of high-quality evidence directly comparing the outcomes of conservative management and ACL repair underscores the importance of personalized treatment plans that align with each patient's unique needs and expectations.

(Evidence Grade: C)

***"Statement 5: In the skeletally immature population, primary ACL repair is less invasive and has less disturbance to the growth plates compared with ACL reconstruction. However, owing to the high rate of graft failure reported in this population, it should not be the gold standard."***

**Agree: 81.82%.**

The ideal treatment for ACL injury in skeletally immature patients remains controversial. Although conservative management has been the mainstay of treatment, poor outcomes have led to the development of several surgical techniques aimed at stabilizing the knee, optimizing outcomes, and minimizing the chances of growth disturbance [74].

The evidence on the failure rate or return to sports after ACL repair is conflicting. Steadman *et al*. observed 23% of patients in a small cohort of patients aged 2–10 yo at a mean follow-up of 6 years [75]. Contrastingly, Gagliardi *et al*. found a significantly higher failure rate in ACL repairs enhanced with suture ligament augmentation compared to repairs using a quadriceps tendon-patellar bone autograft [76]. Yet, Bigoni *et al*. reported promising short-term outcomes for proximal ACL avulsion tears treated with transosseous fixation, a technique favorable for its minimal impact on the growth plate [77].

ACL reconstruction is known to cause potential damage to the physes, which may lead to growth disturbances [78], and has a failure rate of approximately 20% in male athletes [79]. However, in terms of revision rates and knee laxity, ACL reconstruction is superior to conservative treatment and ACL repair [80]. Whether ACL repair is the gold standard for skeletally immature populations remains debatable. Although it appears to be less invasive initially, young age is a risk factor for surgical failure during ACL repair.

(Evidence Grade: C)

***"Statement 6: ACL repair needs to be performed in the acute phase. Following failed rehabilitation, ACL reconstruction is the optimal choice."***

**Agree: 72.73%.**

Ligament retraction and absorption have been reported to occur within a few weeks following the ACL injury [81, 82]. As a result, it has been recommended that primary repair of the ACL be performed within 6 weeks of the injury, which is based mostly on animal studies that have shown retraction of the ligament over time [37, 42, 81, 83, 84]. A review of recent case series on arthroscopic primary repair in pediatric patients revealed that the number of days from injury to surgery ranged between 7 and 123 days [77, 85]. In addition, evidence has shown that adequate tissue of good quality is the primary indication for ACL repair, which is often observed in the subacute phase between 2 weeks and 3 months [20, 83, 86]. Vermeijden *et al*. compared delayed versus acute settings of primary repair of proximal ACL tears and found that their results were similar in clinical and functional outcomes at a minimum 2-year follow-up [87]. Laboratory studies have shown that the remnant shows a high healing potential within three months of the ACL injury [88]. It should be noted that surgery performed 1 week after injury may increase the risk of arthrofibrosis because soft tissue swelling and inflammatory responses in the knee are severe [89].

To date, studies on the effect of preoperative rehabilitation on outcomes after ACL repair are lacking. Progressive preoperative rehabilitation, including protecting the unstable knee, reducing swelling, maintaining quadriceps function, and maximizing knee extension, is useful for treating the initial impairments [90–94]. If rehabilitation does not provide a satisfactory outcome, operative intervention needs to be pursued [95]. Based on the published preoperative rehabilitation program, the time course of rehabilitation before ACL repair will not exceed the acute phase; however, high-quality evidence is necessary prior to drawing conclusions.

(Evidence Grade: C)

***"Statement 7: When suitable cases are selected, ACL repair, including internal brace augmentation, can improve the mechanical environment of the ACL tear."***

**Agree: 54.55%.**

There is limited evidence to support the interaction between the internal brace augmentation technique and intra-articular environment. Currently, available evidence on the outcomes of internal brace augmentation for ACL repair includes only level 3 or 4 studies [76, 96–104]. In a meta-analysis of 347 patients, the total failure rate of ACL repair with internal brace augmentation was 10.4% at a mean follow-up of 2.7 years [105]. Cruz *et al*. also reported a failure rate of 26.1% at a minimum of 2 years of follow-up in a highly active military population [106]. Dabis *et al*. reported that in a pediatric cohort re-operation was considered the standard care in all skeletally immature patients to release the internal brace three months postoperatively [97]. However, these results should be interpreted with caution, as most of the results were from uncontrolled case series. Future randomized controlled studies will provide more information on this [107, 108].

(Evidence Grade: C)

***"Statement 8: ACL repair, together with an anterolateral extra-articular procedure, may reduce the re-rupture rate, but the evidence is inconclusive."***

**Agree: 90.91%.**

There are concerns about the potentially high rates of secondary ipsilateral ACL injuries with repair. A potential solution could be the addition of a lateral extra-articular procedure. Numerous comparative studies have reported that this procedure is highly effective in reducing graft rupture

rates after ACL reconstruction. However, literature on ACL repair combined with lateral extra-articular procedure is limited [109]. Level 2 evidence reported by Ferretti *et al*. showed that ACL repair combined with anterolateral structure repair yielded clinical outcomes that were noninferior to those of ACL reconstruction plus lateral extra-articular tenodesis with respect to function scores, knee laxity parameters, graft maturity, and rates of failure and re-operation at a mean follow-up of 25.2 months. In addition, ACL repair and anterolateral structure repair resulted in shorter times to return to the preinjury level of sport [110].

The addition of a lateral extra-articular procedure restores normal knee kinematics more reliably than isolated ACL reconstruction, and the mechanical environment and constraints experienced by the graft are factors that influence the integration process [111]. Consistent with this, Cavaignac *et al*. demonstrated that MRI parameters evaluating ACL graft incorporation and maturation were favorably influenced by adding lateral extra-articular tenodesis to ACL reconstruction [112]. However, prior to drawing the conclusion that anterolateral extra-articular procedures may benefit patients by improving overall performance after surgery, medium- to long-term follow-up studies are required.

(Evidence Grade: B)

***"Statement 9: In the case of good indication, ACL primary repair can achieve equivalent clinical outcomes as ACL reconstruction in the medium- to long-term among active patients wishing to return to jumping, cutting, and pivoting sports."***

**Agree: 81.82%.**

ACL reconstruction remains the gold standard for patients who wish to return to high activity levels. Nevertheless, growing evidence has shown that optimal outcomes can be expected when indications, including age, activity, special tear type, and tissue quality, are carefully selected. Studies have reported comparable knee function after ACL repair and ACL reconstruction at 1–2-year follow-ups [19, 35, 37–40, 42, 113]. Compared with ACL reconstruction, individuals undergoing ACL repair demonstrate greater limb symmetry during a single-leg squat task three months postoperatively [26] and quicker return of normal knee ROM with a trend toward decreased complications [27]. Additionally, as previously discussed in statement 5, in the skeletally immature population, primary ACL repair is less invasive and causes less disturbance to the growth plates than ACL reconstruction.

ACL repair has its merits in terms of the function end. However, in terms of revision rates and knee laxity, ACL reconstruction is superior to conservative treatment and ACL repair [80]. Taken together, appropriate indications and joint decision-making by the patient, doctor, and team of physician are critical before the surgical procedure is performed, especially in patients aged <20 years.

(Evidence Grade: C)

***"Statement 10: There is limited evidence to support that biological augmentation can improve tissue healing in ACL repair."***

**Agree: 90.91%.**

Biological agents such as platelet-rich plasma (PRP) or mesenchymal stem cells (MSCs) are used to treat partial ruptures or enhance ligamentization following reconstruction. The rationale for their use is to stimulate a population of perivascular tissue-specific stem cells in the septum between the two bundles of the ACL to enhance ligament healing capacity [114, 115]. Only a limited number of cohort studies and case series have reported the application of PRP or MSCs in ACL partial injury as a conservative treatment or combined with ACL repair [18, 116–120]. Based on the current evidence, there is a paucity of data on the role of biologic agents in ACL repair procedures, and the overall quality of the available evidence is modest [121]. Furthermore, the lack of standardization in the application methods for both PRP and MSCs is currently the main limitation in the interpretation of data and study comparisons.

In recent years, there has been a growing interest in novel augmentation techniques for ACL injuries, including both biological agents and biomaterials, which could even be combined together [122, 123]. When dealing with mid-substance ACL tears, the BEAR technique achieved comparable outcomes in terms of subjective scores and arthrometric measurements to ACL reconstruction [19].

We still do not know which strategy is the most advantageous for treating specific conditions. Biological products should be regarded as an opportunity for clinicians; however, their use should not be promoted without collecting sufficient evidence on their effectiveness.

(Evidence Grade: A2)

***"Statement 11: High-quality evidence and long-term outcome analyses are required on post-traumatic osteoarthritis (PTOA) following ACL repair."***

**Agree: 90.91%.**

The development of PTOA is multifactorial [124]. ACL rupture can affect joint biomechanics and cause chondral and meniscal lesions, thereby reducing joint sustainability. The prevalence of PTOA was found to increase in patients with ACL injury after both operative and nonoperative treatments, compared with that in patients without injury [125–127]. However, evidence on PTOA following operative or non-operative treatments is inconclusive [55]. Although ACL repair techniques have evolved in recent years, data on the long-term outcomes of ACL repair are still lacking. An animal study showed that controlling knee stability plays a protective role in OA development [128]. Theoretically, ACL repair is less invasive and has a lower donor-side morbidity. However, whether it can restore the ACL anatomy remains debatable. Therefore, although experimental studies have suggested that primary repair may decrease the risk of OA compared with ACL reconstruction [129, 130], the current lack of high-quality evidence limits conclusions on the possible protective effect of ACL repair.

(Evidence Grade: E)

***"Statement 12: Age, activity level, interval from injury-to-surgery, and ACL tear pattern are risk factors that should be considered when performing ACL repair."***

**Agree: 100%.**

The reasons for ACL repair failure are likely multifactorial, and the indications must be critically reviewed and refined to reduce clinical failure.

ACL repair has been reported to have good outcomes in a subgroup of patients with proximal tears in both historical [9, 44, 131, 132] and modern literature [20, 21, 83, 133–136]. A level II study performed by Krismer *et al*. demonstrated that the location of the mid-substance ACL rupture was a

negative predictor of repair failure [135]. Disruption of the synovial sheath in two- or more-part tears was identified as an independent factor that influences treatment failure in primary ACL repair (odds ratio [OR], 8.9; 95% confidence interval [CI], 2.0–40.0) [137].

Age was found to significantly affect patient outcomes. The failure rate of primary repair of proximal ACL tears is high in patients ≤21 years (37%), compared with that in patients older than 21 years (2.5%) [104]. Gagliardi *et al*. also reported that the cumulative incidence of graft failure in the first 3 years after ACL repair was 48.8% in adolescent patients [76]. Young individuals are more likely to be exposed to environments that place high demands on the knee, which presents the most significant risk factor for further ACL injury [138]. This perspective is supported by studies showing that the pursuit of competitive sports activities with a Tegner preinjury score of >7 is another risk factor for ACL repair failure [99, 135].

The optimal time to return-to-sports after treatment for ACL injuries remains controversial. Vermeijden *et al*. reported that patients feel ready to return to sport within the first 6 postoperative months and suggested that these early returns were because the patients felt that their knee was "normal" quite early on after the surgery [104]. In contrast, poor healing of the ACL (grade 3 on MRI) at 6 months postoperatively has a higher chance of re-rupture in adults [99]. This situation highlights the delicate balance between positive outcomes, such as the ability to quickly achieve the goal of returning to sports, and the negative consequences of a premature return, potentially contributing to repair failure [138]. The roles of return-to-sports testing and formal return-to-play programs have not been rigorously evaluated in the context of ACL repair.

(Evidence Grade: B2)

***"Statement 13: Patient selection is critical and key to the success of the technique. ACL repairs are best indicated for patients with an acute, proximal ACL injury with good-quality ligament remnants."***

**Agree: 100%.**

The indications for ACL repair are critical for optimal outcomes. Proximal tears have been reported to have good outcomes following ACL repair in both historical [9, 44, 131, 132] and modern literature [20, 21, 83, 133–136].

Whether ACL repair should be performed during the acute phase has been a debated topic among the panelists, and it was discussed in the previous statement. A prolonged delay between injury and surgery can cause retraction and scarring of the ACL, which may lead to functional loss of healing potential [54]. Therefore, the injury-to-surgery time interval was regarded as an indicator of tissue quality. Thus, tear location and tissue quality are primary concerns when performing ACL repair. The injury-to-surgery interval is an important indicator of tissue quality. Arthroscopic evaluation is the gold standard for assessing tissue quality.

(Evidence Grade: B2)

***"Statement 14: Postoperative rehabilitation protocol of ACL repair is similar to that of ACL reconstruction and advances more quickly, depending on the individual."***

**Agree: 63.64%.**

Postoperative rehabilitation is critical for successful recovery following ACL repair and should be coordinated with the surgical technique to regulate the strain on the healing ACL. Therefore, the rehabilitation protocol and progression of ACL repair should differ from those of ACL reconstruction. ACL repair has the benefit of no donor site morbidity, resulting in reduced pain and swelling and improved quadriceps function, allowing for smoother progression through the early stages of rehabilitation [139]. However, information from randomized trials is lacking [140].

Recommendations regarding bracing, ROM restrictions, weight-bearing status, exercise progression, and return-to-sports among the different repair techniques vary widely [141]. In addition, consensus on what these postoperative protocols should entail is lacking [140, 142]. Bousquet *et al*. developed a criterion-based rehabilitation progression based on physiological healing frames for ACL primary repair [143]. Each repair technique has implications for the strength of repair at various stages of recovery. For example, at the early stage following surgery, DIS and IBLA are inherently stable, whereas the suture site of the BEAR and SAR are less stable. Therefore, the use of a brace, progression of ROM, and weight-bearing programs should be prolonged or delayed in BEAR and SAR [93, 139, 141].

Therefore, rehabilitation protocols should be examined more thoroughly to establish an agreed-upon and standardized program following ACL repair. Without a standardized rehabilitation protocol, it would not be possible to compare the outcomes following ACL repair with those following ACL reconstruction.

(Evidence Grade: C)

## Discussion

There has been a resurgence of interest in the application of ACL repair to treat ACL deficiencies. Emerging evidence shows comparable outcomes of ACL repair and ACL reconstruction at short to mid-term follow-ups [19, 35, 37–40, 42, 113]. A literature review revealed that high-quality studies and long-term follow-up on the clinical outcomes of ACL repair are limited [42]. Therefore, it is necessary to formulate a global consensus involving doctors specialized in the field who have performed a large number of ACL repairs and published several scholarly papers. Their insights and understanding are of great value in clinical practice and decision-making.

The current consensus covered topics including surgical indications, decision-making, diagnostic methods such as MRI, surgical techniques, adjunctive methods, prognostic factors, and rehabilitation after ACL repair. The consensus provides very clear opinions on certain issues, whereas others remain quite controversial and require more research evidence to guide clinical work.

First, the intrinsic healing potential of ACL is a fundamental concern prior to ACL repair [72, 88, 111, 144, 145]. In this context, proximal tears and tissue quality are primary indicators of successful ACL repair. Although MRI can be used to define tear location and tissue quality, arthroscopic inspection, and evaluation remain the gold standard.

Second, patient characteristics, such as age, activity level, and injury-to-surgery interval, are important prognostic factors in decision-making. Some experts have claimed that ACL repair should not be performed during the acute phase if the tear location and tissue quality are adequate for repair [146]. Nevertheless, injury during the surgery interval is still a proxy for tissue quality. In addition, the ideal treatment for ACL injuries in skeletally immature patients remains controversial. ACL repair has the advantage of avoiding epiphyseal plate disruption, and the high rate of re-rupture cannot be neglected.

Third, biological augmentation and additional surgical procedures, such as anterolateral extra-articular fixation, have garnered great interest. Both techniques may enhance ligament healing or improve joint stability; however, further investigation is required.

ACL reconstruction inevitably causes donor site morbidity and delays return-to-sports. The ACL repair technique has the advantages of reduced pain and swelling during the early phase after surgery and an earlier return-to-sports because of the absence of a graft harvest. Nevertheless, ACL reconstruction remains the gold standard until >5-year follow-up on ACL repair data can show otherwise. Whether ACL repair can prevent traumatic OA remains unclear, although laboratory research suggests that ACL repair can maintain the knee mechanism.

However, this consensus statement has some limitations. The literature review identified a limited number of studies with high levels of evidence, and the expert opinions were mainly based on an understanding of the current studies. Therefore, this article should not be considered a final statement or guideline, as deeper insights will continue to emerge in the future.

## Conclusions

This expert consensus statement focused on surgical indications, decision-making, surgical techniques, adjunctive methods, prognostic factors, and rehabilitation following ACL repair. Acceptable recommendations in these areas may assist doctors and therapists in standardizing the management of related pathologies. This consensus clearly states that tear location and tissue quality are important for ensuring successful ACL repair, while other factors should also be considered. ACL reconstruction remains the gold standard until long-term follow-up data on ACL repair can demonstrate otherwise.

## Acknowledgments

Department of Sports Medicine of Huashan Hospital affiliated to Fudan University was the primary institution where this investigation was performed.

## Author contributions

Shurong Zhang, Tian Xia, Xuesong Dai (Investigation [equal]), Gregory S. DiFelice (Investigation [equal]), Lars Engebretsen (Investigation [equal]), Alberto Gobbi (Investigation [equal]), Christiaan H. Heusdens (Investigation [equal]), Gordon M. MacKay (Investigation [equal]), Bertrand Sonnery-cottetx (Investigation [equal]), Jelle P. van der List (Investigation [equal]), Shu-Hang P. Yung (Investigation [equal]), Jianquan Wang (Investigation [equal]), and Yinghui Hua (Project Administration [equal])

## Ethics approval and consent to participate

Not applicable.

## Consent for publication

Not applicable.

## Conflict of interest

The authors declare that they have no conflict of interest.

## Funding

This work was supported by the National Key R&D Program of China (No. 2021YFA1201303), and Shanghai Hospital Development Center (No. SHDC2022CRT021).

## Data availability

The voting results are available upon reasonable request to the corresponding senior authors (Yinghui Hua, hua_cosm@aliyun.com). The results of this study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

## Registration of consensus and guideline

International Practice Guideline Registry Platform, PREPARE-2022CN806.

## References

1. Marshall JL, Warren RF, Wickiewicz TL, Reider B. The anterior cruciate ligament: a technique of repair and reconstruction. *Clin Orthop Relat Res* 1979;97–106. https://doi.org/10.1097/00003086-197909000-00014.
2. Feagin JA Jr, Curl WW. Isolated tear of the anterior cruciate ligament: 5-year follow-up study. *Am J Sports Med* 1976;**4**:95–100. https://doi.org/10.1177/036354657600400301.
3. Kandhari V, Vieira TD, Ouanezar H, Praz C, Rosenstiel N, Pioger C. *et al.* Clinical outcomes of arthroscopic primary anterior cruciate ligament repair: a systematic review from the scientific anterior cruciate ligament network international study group. *Arthroscopy* 2020;**36**:594–612. https://doi.org/10.1016/j.arthro.2019.09.021.
4. Holsgaard-Larsen A, Jensen C, Mortensen NH, Aagaard P. Concurrent assessments of lower limb loading patterns, mechanical muscle strength and functional performance in ACL-patients—a cross-sectional study. *Knee* 2014;**21**:66–73. https://doi.org/10.1016/j.knee.2013.06.002.
5. Konrath JM, Vertullo CJ, Kennedy BA, Bush HS, Barrett RS, Lloyd DG. Morphologic characteristics and strength of the hamstring muscles remain altered at 2 years after use of a hamstring tendon graft in anterior cruciate ligament reconstruction. *Am J Sports Med* 2016;**44**:2589–98. https://doi.org/10.1177/0363546516651441.
6. Dabis J, Wilson A. Repair and augmentation with internal brace in the multiligament injured knee. *Clin Sports Med* 2019;**38**:275–83. https://doi.org/10.1016/j.csm.2018.11.008.
7. Taylor SA, Khair MM, Roberts TR, DiFelice GS. Primary repair of the anterior cruciate ligament: a systematic review. *Arthroscopy* 2015;**31**:2233–47. https://doi.org/10.1016/j.arthro.2015.05.007.
8. Drogset JO, Grøntvedt T, Robak OR, Mølster A, Viset AT, Engebretsen L. A sixteen-year follow-up of three operative techniques for the treatment of acute ruptures of the anterior cruciate ligament. *J Bone Joint Surg Am* 2006;**88**:944–52. https://doi.org/10.2106/JBJS.D.02876.
9. van der List JP, DiFelice GS. Primary repair of the anterior cruciate ligament: a paradigm shift. *Surgeon* 2017;**15**:161–8. https://doi.org/10.1016/j.surge.2016.09.006.
10. Deie M, Ochi M, Ikuta Y. High intrinsic healing potential of human anterior cruciate ligament. Organ culture experiments. *Acta Orthop Scand* 1995;**66**:28–32. https://doi.org/10.3109/17453679508994634.

11. Voloshin I, Bronstein RD, DeHaven KE. Spontaneous healing of a patellar tendon anterior cruciate ligament graft. A case report. *Am J Sports Med* 2002;**30**:751–3.
12. Filbay SR, Roemer FW, Lohmander LS, Turkiewicz A, Roos EM, Frobell R. *et al.* Evidence of ACL healing on MRI following ACL rupture treated with rehabilitation alone may be associated with better patient-reported outcomes: a secondary analysis from the KANON trial. *Br J Sports Med* 2023;**57**:91–9. https://doi.org/10.1136/bjsports-2022-105473.
13. Murray MM, Fleming BC. Biology of anterior cruciate ligament injury and repair: kappa delta ann doner Vaughn award paper 2013. *J Orthop Res* 2013;**31**:1501–6. https://doi.org/10.1002/jor.22420.
14. Murray MM, Flutie BM, Kalish LA, Ecklund K, Fleming BC, Proffen BL. *et al.* The bridge-enhanced anterior cruciate ligament repair (BEAR) procedure: an early feasibility cohort study. *Orthop J Sports Med* 2016;**4**:2325967116672176. https://doi.org/10.1177/2325967116672176.
15. Eggli S, Kohlhof H, Zumstein M, Henle P, Hartel M, Evangelopoulos DS. *et al.* Dynamic intraligamentary stabilization: novel technique for preserving the ruptured ACL. *Knee Surg Sports Traumatol Arthrosc* 2015;**23**:1215–21. https://doi.org/10.1007/s00167-014-2949-x.
16. Mackay GM, Blyth MJ, Anthony I, Hopper GP, Ribbans WJ. A review of ligament augmentation with the InternalBrace™: the surgical principle is described for the lateral ankle ligament and ACL repair in particular, and a comprehensive review of other surgical applications and techniques is presented. *Surg Technol Int* 2015;**26**:239–55.
17. Wilson WT, Hopper GP, Byrne PA, MacKay GM. Anterior cruciate ligament repair with internal brace ligament augmentation. *Surg Technol Int* 2016;**29**:273–8.
18. Gobbi A, Whyte GP. Long-term outcomes of primary repair of the anterior cruciate ligament combined with biologic healing augmentation to treat incomplete tears. *Am J Sports Med* 2018;**46**:3368–77.
19. Murray MM, Fleming BC, Badger GJ, The BEAR Trial Team, Freiberger C, Henderson R. *et al.* Bridge-enhanced anterior cruciate ligament repair is not inferior to autograft anterior cruciate ligament reconstruction at 2 years: results of a prospective randomized clinical trial. *Am J Sports Med* 2020;**48**:1305–15. https://doi.org/10.1177/0363546520913532.
20. DiFelice GS, Villegas C, Taylor S. Anterior cruciate ligament preservation: early results of a novel arthroscopic technique for suture anchor primary anterior cruciate ligament repair. *Arthroscopy* 2015;**31**:2162–71. https://doi.org/10.1016/j.arthro.2015.08.010.
21. Heusdens CHW, Hopper GP, Dossche L, Mackay GM. Anterior cruciate ligament repair using independent suture tape reinforcement. *Arthrosc Tech* 2018;**7**:e747–53. https://doi.org/10.1016/j.eats.2018.03.007.
22. Kohl S, Evangelopoulos DS, Kohlhof H, Hartel M, Bonel H, Henle P. *et al.* Anterior crucial ligament rupture: self-healing through dynamic intraligamentary stabilization technique. *Knee Surg Sports Traumatol Arthrosc* 2013;**21**:599–605. https://doi.org/10.1007/s00167-012-1958-x.
23. Zhang S, Chen G, Li R, Yang C, Zheng J, Wang C. *et al.* Guidelines on the diagnosis and treatment of lateral meniscal lesions: a consensus statement by the Chinese Society of Sports Medicine. *Orthop J Sports Med* 2022;**10**:23259671221138082. https://doi.org/10.1177/23259671221138082.
24. Webster KE, Wittwer JE, O'Brien J, Feller JA. Gait patterns after anterior cruciate ligament reconstruction are related to graft type. *Am J Sports Med* 2005;**33**:247–54. https://doi.org/10.1177/0363546504266483.
25. Lepley LK. Deficits in quadriceps strength and patient-oriented outcomes at return to activity after ACL reconstruction: a review of the current literature. *Sports Health* 2015;**7**:231–8. https://doi.org/10.1177/1941738115578112.
26. Singleton S, Scofield H, Davis B, Waller A, Garrison C, Goto S. *et al.* Altered knee loading following primary ACL repair versus ACL reconstruction. *Int J Sports Phys Ther* 2023;**V18**:596–605. https://doi.org/10.26603/001c.77362.
27. van der List JP, DiFelice GS. Range of motion and complications following primary repair versus reconstruction of the anterior cruciate ligament. *Knee* 2017;**24**:798–807. https://doi.org/10.1016/j.knee.2017.04.007.
28. Barenius B, Ponzer S, Shalabi A, Bujak R, Norlén L, Eriksson K. Increased risk of osteoarthritis after anterior cruciate ligament reconstruction: a 14-year follow-up study of a randomized controlled trial. *Am J Sports Med* 2014;**42**:1049–57. https://doi.org/10.1177/0363546514526139.
29. Zwolski C, Schmitt LC, Quatman-Yates C, Thomas S, Hewett TE, Paterno MV. The influence of quadriceps strength asymmetry on patient-reported function at time of return to sport after anterior cruciate ligament reconstruction. *Am J Sports Med* 2015;**43**:2242–9. https://doi.org/10.1177/0363546515591258.
30. Kessler MA, Behrend H, Henz S, Stutz G, Rukavina A, Kuster MS. Function, osteoarthritis and activity after ACL-rupture: 11 years follow-up results of conservative versus reconstructive treatment. *Knee Surg Sports Traumatol Arthrosc* 2008;**16**:442–8. https://doi.org/10.1007/s00167-008-0498-x.
31. Wang LJ, Zeng N, Yan ZP, Li JT, Ni GX. Post-traumatic osteoarthritis following ACL injury. *Arthritis Res Ther* 2020;**22**:57. https://doi.org/10.1186/s13075-020-02156-5.
32. Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L, Risberg MA. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *Br J Sports Med* 2016;**50**:804–8. https://doi.org/10.1136/bjsports-2016-096031.
33. Schmitt LC, Paterno MV, Hewett TE. The impact of quadriceps femoris strength asymmetry on functional performance at return to sport following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther* 2012;**42**:750–9. https://doi.org/10.2519/jospt.2012.4194.
34. Vermeijden HD, Holuba K, Yang XA, O'Brien R, van der List JP, DiFelice GS. Prospective comparison of postoperative pain and opioid consumption between primary repair and reconstruction of the anterior cruciate ligament. *Orthop J Sports Med.* 2023;**11**:23259671231187442. https://doi.org/10.1177/23259671231187442.
35. Bühl L, Müller S, Nüesch C, Boyer KA, Casto E, Mündermann A. *et al.* Ambulatory knee biomechanics and muscle activity 2 years after ACL surgery: InternalBrace(TM)-augmented ACL repair versus ACL reconstruction versus healthy controls. *BMC Musculoskelet Disord* 2023;**24**:785. https://doi.org/10.1186/s12891-023-06916-7.
36. Douoguih WA, Apseloff NA, Murray JC, Kelly RL, Svoboda SJ. Suture-augmented ACL repair for proximal avulsion or high-grade partial tears shows similar side-to-side difference and No clinical differences at two years versus conventional ACL reconstruction for mid-substance tears or poor ACL tissue quality. *Arthroscopy* 2023;**40**:857–67. https://doi.org/10.1016/j.arthro.2023.07.011.
37. Hoogeslag RAG, Brouwer RW, Boer BC, de Vries AJ, Huis In 't Veld R. Acute anterior cruciate ligament rupture: repair or reconstruction? Two-year results of a randomized controlled clinical trial. *Am J Sports Med* 2019;**47**:567–77. https://doi.org/10.1177/0363546519825878.
38. Kösters C, Glasbrenner J, Spickermann L, Kittl C, Domnick C, Herbort M. *et al.* Repair with dynamic Intraligamentary stabilization versus primary reconstruction of acute anterior cruciate ligament tears: 2-year results from a prospective randomized study. *Am J Sports Med* 2020;**48**:1108–16. https://doi.org/10.1177/0363546520905863.
39. Schliemann B, Glasbrenner J, Rosenbaum D, Lammers K, Herbort M, Domnick C. *et al.* Changes in gait pattern and early functional

results after ACL repair are comparable to those of ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2018;**26**:374–80. https://doi.org/10.1007/s00167-017-4618-3.
40. Shen Z, Chen H, Ye M, Gao Z, Li H, Lu H. *et al.* Early outcomes of primary repair versus reconstruction for acute anterior cruciate ligament injury: a systematic review and meta-analysis. *Medicine (Baltimore)* 2022;**101**:e32411. https://doi.org/10.1097/MD.0000000000032411.
41. Migliorini F, Vecchio G, Eschweiler J, Schneider SM, Hildebrand F, Maffulli N. Reduced knee laxity and failure rate following anterior cruciate ligament reconstruction compared with repair for acute tears: a meta-analysis. *J Orthop Traumatol* 2023;**24**:8. https://doi.org/10.1186/s10195-023-00688-5.
42. Hoogeslag RAG, Huis In 't Veld R, Brouwer RW, de Graaff F, Verdonschot N. Acute anterior cruciate ligament rupture: repair or reconstruction? Five-year results of a randomized controlled clinical trial. *Am J Sports Med* 2022;**50**:1779–87. https://doi.org/10.1177/03635465221090527.
43. Connaughton AJ, Geeslin AG, Uggen CW. All-inside ACL reconstruction: how does it compare to standard ACL reconstruction techniques? *J Orthop* 2017;**14**:241–6. https://doi.org/10.1016/j.jor.2017.03.002.
44. Sherman MF, Lieber L, Bonamo JR, Podesta L, Reiter I. The long-term followup of primary anterior cruciate ligament repair. Defining a rationale for augmentation. *Am J Sports Med* 1991;**19**:243–55. https://doi.org/10.1177/036354659101900307.
45. Marshall JL, Warren RF, Wickiewicz TL. Primary surgical treatment of anterior cruciate ligament lesions. *Am J Sports Med* 1982;**10**:103–7. https://doi.org/10.1177/036354658201000208.
46. Strand T, Engesaeter LB, Mølster AO, Raugstad TS, Stangeland L, Stray O. *et al.* Knee function following suture of fresh tear of the anterior cruciate ligament. *Acta Orthop Scand* 1984;**55**:181–4. https://doi.org/10.3109/17453678408992333.
47. Weaver JK, Derkash RS, Freeman JR, Kirk RE, Oden RR, Matyas J. Primary knee ligament repair???Revisited. *Clin Orthop Relat Res* 1985;**199**:185–91. https://doi.org/10.1097/00003086-198510000-00026.
48. van der List JP, DiFelice GS. Preservation of the anterior cruciate ligament: a treatment algorithm based on tear location and tissue quality. *Am J Orthop (Belle Mead NJ)* 2016;**45**:E393–e405.
49. Bräm J, Plaschy S, Lütolf M, Leutenegger A. The primary cruciate ligament suture–is the method outdated? Results in follow-up of 58 patients. *Z Unfallchir Versicherungsmed* 1994;**87**:91–109.
50. Genelin F, Trost A, Primavesi C, Knoll P. Late results following proximal reinsertion of isolated ruptured ACL ligaments. *Knee Surg Sports Traumatol Arthrosc* 1993;**1**:17–9. https://doi.org/10.1007/BF01552153.
51. Higgins RW, Steadman JR. Anterior cruciate ligament repairs in world class skiers. *Am J Sports Med* 1987;**15**:439–47. https://doi.org/10.1177/036354658701500503.
52. Kühne JH, Refior HJ. Primary suture of the anterior cruciate ligament. A critical analysis. *Unfallchirurg* 1993;**96**:451–6.
53. Simonet WT, Sim FH. Repair and reconstruction of rotatory instability of the knee. *Am J Sports Med* 1984;**12**:89–97. https://doi.org/10.1177/036354658401200201.
54. Murray MM, Martin SD, Martin TL, Spector M. Histological changes in the human anterior cruciate ligament after rupture. *J Bone Joint Surg Am* 2000;**82**:1387–97. https://doi.org/10.2106/00004623-200010000-00004.
55. Diermeier T, Rothrauff BB, Engebretsen L, Lynch AD, Ayeni OR, Paterno MV. *et al.* Treatment after anterior cruciate ligament injury: panther symposium ACL treatment consensus group. *Knee Surg Sports Traumatol Arthrosc* 2020;**28**:2390–402. https://doi.org/10.1007/s00167-020-06012-6.
56. Gee MSM, Peterson CDR, Zhou ML, Bottoni CR. Anterior cruciate ligament repair: historical perspective, indications, techniques, and outcomes. *J Am Acad Orthop Surg* 2020;**28**:963–71. https://doi.org/10.5435/JAAOS-D-20-00077.
57. Mink JH, Levy T, Crues JV 3rd. Tears of the anterior cruciate ligament and menisci of the knee: MR imaging evaluation. *Radiology* 1988;**167**:769–74. https://doi.org/10.1148/radiology.167.3.3363138.
58. Turner DA, Prodromos CC, Petasnick JP, Clark JW. Acute injury of the ligaments of the knee: magnetic resonance evaluation. *Radiology* 1985;**154**:717–22. https://doi.org/10.1148/radiology.154.3.3969476.
59. Volokhina YV, Syed HM, Pham PH, Blackburn AK. Two helpful MRI signs for evaluation of posterolateral bundle tears of the anterior cruciate ligament: a pilot study. *Orthop J Sports Med*. 2015;**3**:2325967115597641. https://doi.org/10.1177/2325967115597641.
60. Barberie JE, Carson BW, Finnegan M, Wong AD. Oblique sagittal view of the anterior cruciate ligament: comparison of coronal vs. axial planes as localizing sequences. *J Magn Reson Imaging* 2001;**14**:203–6. https://doi.org/10.1002/jmri.1174.
61. Kosaka M, Nakase J, Toratani T, Ohashi Y, Kitaoka K, Yamada H. *et al.* Oblique coronal and oblique sagittal MRI for diagnosis of anterior cruciate ligament tears and evaluation of anterior cruciate ligament remnant tissue. *Knee* 2014;**21**:54–7. https://doi.org/10.1016/j.knee.2013.04.016.
62. Park HJ, Lee SY, Park NH, Ahn JH, Chung EC, Kim SJ. *et al.* Three-dimensional isotropic T2-weighted fast spin-echo (VISTA) knee MRI at 3.0 T in the evaluation of the anterior cruciate ligament injury with additional views: comparison with two-dimensional fast spin-echo T2-weighted sequences. *Acta Radiol* 2016;**57**:1372–9. https://doi.org/10.1177/0284185114568048.
63. Daniels SP, van der List JP, Kazam JJ, DiFelice GS. Arthroscopic primary repair of the anterior cruciate ligament: what the radiologist needs to know. *Skeletal Radiol* 2018;**47**:619–29. https://doi.org/10.1007/s00256-017-2857-5.
64. van der List JP, DiFelice GS. Preoperative magnetic resonance imaging predicts eligibility for arthroscopic primary anterior cruciate ligament repair. *Knee Surg Sports Traumatol Arthrosc* 2018;**26**:660–71. https://doi.org/10.1007/s00167-017-4646-z.
65. Van Dyck P, Gielen JL, Vanhoenacker FM, Wouters K, Dossche L, Parizel PM. Stable or unstable tear of the anterior cruciate ligament of the knee: an MR diagnosis? *Skeletal Radiol* 2012;**41**:273–80. https://doi.org/10.1007/s00256-011-1169-4.
66. Brandser EA, Riley MA, Berbaum KS, el-Khoury GY, Bennett DL. MR imaging of anterior cruciate ligament injury: independent value of primary and secondary signs. *AJR Am J Roentgenol* 1996;**167**:121–6. https://doi.org/10.2214/ajr.167.1.8659355.
67. Van Dyck P, De Smet E, Veryser J, Lambrecht V, Gielen JL, Vanhoenacker FM. *et al.* Partial tear of the anterior cruciate ligament of the knee: injury patterns on MR imaging. *Knee Surg Sports Traumatol Arthrosc* 2012;**20**:256–61. https://doi.org/10.1007/s00167-011-1617-7.
68. Moura JL, Kandhari V, Rosenstiel N, Helfer L, Queirós CM, Abreu FG. *et al.* Figure-of-4 cruciate remnant objective assessment test reducibility of anterior cruciate ligament stump for feasibility of arthroscopic primary anterior cruciate ligament repair. *Arthrosc Tech* 2019;**8**:e637–40. https://doi.org/10.1016/j.eats.2019.02.008.
69. Waite JC, Beard DJ, Dodd CA, Murray DW, Gill HS. In vivo kinematics of the ACL-deficient limb during running and cutting. *Knee Surg Sports Traumatol Arthrosc* 2005;**13**:377–84. https://doi.org/10.1007/s00167-004-0569-6.
70. Ahn JH, Chang MJ, Lee YS, Koh KH, Park YS, Eun SS. Non-operative treatment of ACL rupture with mild instability. *Arch Orthop Trauma Surg* 2010;**130**:1001–6. https://doi.org/10.1007/s00402-010-1077-4.
71. Fujimoto E, Sumen Y, Ochi M, Ikuta Y. Spontaneous healing of acute anterior cruciate ligament (ACL) injuries - conservative treatment using an extension block soft brace without anterior stabilization. *Arch Orthop Trauma Surg* 2002;**122**:212–6. https://doi.org/10.1007/s00402-001-0387-y.

72. Blanke F, Trinnes K, Oehler N, Prall WC, Lutter C, Tischer T. *et al.* Spontaneous healing of acute ACL ruptures: rate, prognostic factors and short-term outcome. *Arch Orthop Trauma Surg* 2023;**143**:4291–8. https://doi.org/10.1007/s00402-022-04701-0.
73. Muaidi QI, Nicholson LL, Refshauge KM, Herbert RD, Maher CG. Prognosis of conservatively managed anterior cruciate ligament injury: a systematic review. *Sports Med* 2007;**37**:703–16. https://doi.org/10.2165/00007256-200737080-00004.
74. Joseph SM, Huleatt JB, Vogel-Abernathie LA, Pace JL. Treatment of ACL tears in the skeletally immature patient. *Sports Med Arthrosc Rev* 2018;**26**:153–6. https://doi.org/10.1097/JSA.0000000000000216.
75. Steadman JR, Cameron-Donaldson ML, Briggs KK, Rodkey WG. A minimally invasive technique ("healing response") to treat proximal ACL injuries in skeletally immature athletes. *J Knee Surg* 2006;**19**:8–13. https://doi.org/10.1055/s-0030-1248070.
76. Gagliardi AG, Carry PM, Parikh HB, Traver JL, Howell DR, Albright JC. ACL repair with suture ligament augmentation is associated with a high failure rate among adolescent patients. *Am J Sports Med* 2019;**47**:560–6. https://doi.org/10.1177/0363546518825255.
77. Bigoni M, Gaddi D, Gorla M, Munegato D, Pungitore M, Piatti M. *et al.* Arthroscopic anterior cruciate ligament repair for proximal anterior cruciate ligament tears in skeletally immature patients: surgical technique and preliminary results. *Knee* 2017;**24**:40–8. https://doi.org/10.1016/j.knee.2016.09.017.
78. Krutsch W, Zellner J, Baumann F, Pfeifer C, Nerlich M, Angele P. Timing of anterior cruciate ligament reconstruction within the first year after trauma and its influence on treatment of cartilage and meniscus pathology. *Knee Surg Sports Traumatol Arthrosc* 2017;**25**:418–25. https://doi.org/10.1007/s00167-015-3830-2.
79. Werner BC, Yang S, Looney AM, Gwathmey FW Jr. Trends in Pediatric and adolescent anterior cruciate ligament injury and reconstruction. *J Pediatr Orthop* 2016;**36**:447–52.
80. Morvan A, Bouguennec N, Graveleau N. ACL injuries before 15 years of age: could the young become an athlete? *Arch Orthop Trauma Surg* 2020;**140**:1055–63. https://doi.org/10.1007/s00402-020-03404-8.
81. O'Donoghue DH. Surgical treatment of fresh injuries to the major ligaments of the knee. *J Bone Joint Surg Am* 1950;**32**:721–38. https://doi.org/10.2106/00004623-195032040-00001.
82. O'Donoghue DH. An analysis of end results of surgical treatment of major injuries to the ligaments of the knee. *J Bone Joint Surg Am* 1955;**37**:1–124. https://doi.org/10.2106/00004623-195537010-00001.
83. Achtnich A, Herbst E, Forkel P, Metzlaff S, Sprenker F, Imhoff AB. *et al.* Acute proximal anterior cruciate ligament tears: outcomes after arthroscopic suture anchor repair versus anatomic single-bundle reconstruction. *Arthroscopy* 2016;**32**:2562–9. https://doi.org/10.1016/j.arthro.2016.04.031.
84. Engebretsen L, Svenningsen S, Benum P. Poor results of anterior cruciate ligament repair in adolescence. *Acta Orthop Scand* 1988;**59**:684–6. https://doi.org/10.3109/17453678809149425.
85. Smith JO, Yasen SK, Palmer HC, Lord BR, Britton EM, Wilson AJ. Paediatric ACL repair reinforced with temporary internal bracing. *Knee Surg Sports Traumatol Arthrosc* 2016;**24**:1845–51. https://doi.org/10.1007/s00167-016-4150-x.
86. van der List JP, DiFelice GS. Arthroscopic primary anterior cruciate ligament repair with suture augmentation. *Arthrosc Tech* 2017;**6**:e1529–34. https://doi.org/10.1016/j.eats.2017.06.009.
87. Vermeijden HD, van der List JP, DiFelice GS. Acute and delayed anterior cruciate ligament repair results in similar short to mid-term outcomes. *Knee* 2021;**29**:142–9. https://doi.org/10.1016/j.knee.2021.01.028.
88. Zhang S, Matsumoto T, Uefuji A, Matsushita T, Takayama K, Araki D. *et al.* Anterior cruciate ligament remnant tissue harvested within 3-months after injury predicts higher healing potential. *BMC Musculoskelet Disord* 2015;**16**:390. https://doi.org/10.1186/s12891-015-0855-0.
89. Wasilewski SA, Covall DJ, Cohen S. Effect of surgical timing on recovery and associated injuries after anterior cruciate ligament reconstruction. *Am J Sports Med* 1993;**21**:338–42.
90. Eitzen I, Holm I, Risberg MA. Preoperative quadriceps strength is a significant predictor of knee function two years after anterior cruciate ligament reconstruction. *Br J Sports Med* 2009;**43**:371–6. https://doi.org/10.1136/bjsm.2008.057059.
91. Eitzen I, Moksnes H, Snyder-Mackler L, Risberg MA. A progressive 5-week exercise therapy program leads to significant improvement in knee function early after anterior cruciate ligament injury. *J Orthop Sports Phys Ther* 2010;**40**:705–21. https://doi.org/10.2519/jospt.2010.3345.
92. Hurd WJ, Axe MJ, Snyder-Mackler L. A 10-year prospective trial of a patient management algorithm and screening examination for highly active individuals with anterior cruciate ligament injury: part 2, determinants of dynamic knee stability. *Am J Sports Med* 2008;**36**:48–56. https://doi.org/10.1177/0363546507308191.
93. Irfan A, Kerr S, Hopper G, Wilson W, Wilson L, Mackay G. A criterion based rehabilitation protocol for ACL repair with internal brace augmentation. *Int J Sports Phys Ther* 2021;**16**:870–8. https://doi.org/10.26603/001c.22217.
94. Shaarani SR, O'Hare C, Quinn A, Moyna N, Moran R, O'Byrne JM. Effect of prehabilitation on the outcome of anterior cruciate ligament reconstruction. *Am J Sports Med* 2013;**41**:2117–27. https://doi.org/10.1177/0363546513493594.
95. Failla MJ, Logerstedt DS, Grindem H, Axe MJ, Risberg MA, Engebretsen L. *et al.* Does extended preoperative rehabilitation influence outcomes 2 years after ACL reconstruction? A comparative effectiveness study between the MOON and Delaware-Oslo ACL cohorts. *Am J Sports Med* 2016;**44**:2608–14. https://doi.org/10.1177/0363546516652594.
96. Burton DA, Schaefer EJ, Shu HT, Bodendorfer BM, Argintar EH. Primary anterior cruciate ligament repair using suture tape augmentation: a case series of 29 patients with minimum 2-year follow-up. *Arthroscopy* 2021;**37**:1235–41. https://doi.org/10.1016/j.arthro.2020.11.034.
97. Dabis J, Yasen SK, Foster AJ, Pace JL, Wilson AJ. Paediatric proximal ACL tears managed with direct ACL repair is safe, effective and has excellent short-term outcomes. *Knee Surg Sports Traumatol Arthrosc* 2020;**28**:2551–6. https://doi.org/10.1007/s00167-020-05872-2.
98. Douoguih WA, Zade RT, Bodendorfer BM, Siddiqui Y, Lincoln AE. Anterior cruciate ligament repair with suture augmentation for proximal avulsion injuries. *Arthrosc Sports Med Rehabil* 2020;**2**:e475–80. https://doi.org/10.1016/j.asmr.2020.05.003.
99. Heusdens CHW, Blockhuys K, Roelant E, Dossche L, Van Glabbeek F, Van Dyck P. Suture tape augmentation ACL repair, stable knee, and favorable PROMs, but a re-rupture rate of 11% within 2 years. *Knee Surg Sports Traumatol Arthrosc* 2021;**29**:3706–14. https://doi.org/10.1007/s00167-020-06399-2.
100. Hopper GP, Aithie JMS, Jenkins JM, Wilson WT, Mackay GM. Satisfactory patient-reported outcomes at 5 years following primary repair with suture tape augmentation for proximal anterior cruciate ligament tears. *Knee Surg Sports Traumatol Arthrosc* 2022;**30**:253–9. https://doi.org/10.1007/s00167-021-06485-z.
101. Jonkergouw A, van der List JP, DiFelice GS. Arthroscopic primary repair of proximal anterior cruciate ligament tears: outcomes of the first 56 consecutive patients and the role of additional internal bracing. *Knee Surg Sports Traumatol Arthrosc* 2019;**27**:21–8. https://doi.org/10.1007/s00167-018-5338-z.
102. Ortmaier R, Fink C, Schobersberger W, Kindermann H, Leister I, Runer A. *et al.* Return to sports after anterior cruciate ligament injury: a matched-pair analysis of repair with internal brace and reconstruction using hamstring or quadriceps tendons. *Sportverletz Sportschaden* 2021;**35**:36–44. https://doi.org/10.1055/a-1019-0949.

103. Schneider KN, Schliemann B, Gosheger G, Theil C, Weller J, Buddhdev PK. *et al.* Good to excellent functional short-term outcome and low revision rates following primary anterior cruciate ligament repair using suture augmentation. *J Clin Med* 2020;**9**. https://doi.org/10.3390/jcm9103068.
104. Vermeijden HD, Yang XA, van der List JP, DiFelice GS. Role of age on success of arthroscopic primary repair of proximal anterior cruciate ligament tears. *Arthroscopy* 2021;**37**:1194–201. https://doi.org/10.1016/j.arthro.2020.11.024.
105. Wilson WT, Hopper GP, Banger MS, Blyth MJG, Riches PE, MacKay GM. Anterior cruciate ligament repair with internal brace augmentation: a systematic review. *Knee* 2022;**35**:192–200. https://doi.org/10.1016/j.knee.2022.03.009.
106. Cruz CA, Mannino BJ, Venrick CB, Miles RN, Peterson DR, Zhou L. *et al.* Failure rates after anterior cruciate ligament repair with suture tape augmentation in an active-duty military population. *Orthopaedic Journal of Sports Medicine* 2023;**11**. https://doi.org/10.1177/23259671221142315.
107. Heusdens CHW, Zazulia K, Roelant E, Dossche L, van Tiggelen D, Roeykens J. *et al.* Study protocol: a single-blind, multi-center, randomized controlled trial comparing dynamic intraligamentary stabilization, internal brace ligament augmentation and reconstruction in individuals with an acute anterior cruciate ligament rupture: LIBRƎ study. *BMC Musculoskelet Disord* 2019;**20**:547. https://doi.org/10.1186/s12891-019-2926-0.
108. van der List JP, Vermeijden HD, Sierevelt IN, Rademakers MV, Falke MLM, Helmerhorst GTT. *et al.* Repair versus reconstruction for proximal anterior cruciate ligament tears: a study protocol for a prospective multicenter randomized controlled trial. *BMC Musculoskelet Disord* 2021;**22**:399. https://doi.org/10.1186/s12891-021-04280-y.
109. Praz C, Kandhari VK, Saithna A, Sonnery-Cottet B. ACL rupture in the immediate build-up to the Olympic games: return to elite alpine ski competition 5 months after injury and ACL repair. *BMJ Case Rep* 2019;**12**. https://doi.org/10.1136/bcr-2018-227735.
110. Ferretti A, Carrozzo A, Saithna A, Argento G, Annibaldi A, Latini F. *et al.* Comparison of primary repair of the anterior cruciate ligament and anterolateral structures to reconstruction and lateral extra-articular Tenodesis at 2-year follow-up. *Am J Sports Med* 2023;**51**:2300–12. https://doi.org/10.1177/03635465231178301.
111. Claes S, Verdonk P, Forsyth R, Bellemans J. The "Ligamentization" process in anterior cruciate ligament reconstruction. *Am J Sports Med* 2011;**39**:2476–83. https://doi.org/10.1177/0363546511402662.
112. Cavaignac E, Mesnier T, Marot V, Fernandez A, Faruch M, Berard E. *et al.* Effect of lateral extra-articular Tenodesis on anterior cruciate ligament graft incorporation. *Orthop J Sports Med* 2020;**8**:2325967120960097. https://doi.org/10.1177/2325967120960097.
113. Müller S, Bühl L, Nüesch C, Pagenstert G, Mündermann A, Egloff C. Favorable patient-reported, clinical, and functional outcomes 2 years after ACL repair and InternalBrace augmentation compared with ACL reconstruction and healthy controls. *Am J Sports Med* 2023;**51**:3131–41. https://doi.org/10.1177/03635465231194784.
114. Leite CBG, Demange MK. Biological enhancements for anterior cruciate ligament reconstruction. *Acta Ortop Bras* 2019;**27**:325–30. https://doi.org/10.1590/1413-785220192706226481.
115. Looney AM, Leider JD, Horn AR, Bodendorfer BM. Bioaugmentation in the surgical treatment of anterior cruciate ligament injuries: a review of current concepts and emerging techniques. *SAGE Open Med* 2020;**8**:2050312120921057. https://doi.org/10.1177/2050312120921057.
116. Centeno C, Markle J, Dodson E, Stemper I, Williams C, Hyzy M. *et al.* Symptomatic anterior cruciate ligament tears treated with percutaneous injection of autologous bone marrow concentrate and platelet products: a non-controlled registry study. *J Transl Med* 2018;**16**:246. https://doi.org/10.1186/s12967-018-1623-3.
117. Centeno CJ, Pitts J, Al-Sayegh H, Freeman MD. Anterior cruciate ligament tears treated with percutaneous injection of autologous bone marrow nucleated cells: a case series. *J Pain Res* 2015;**8**:437–47. https://doi.org/10.2147/JPR.S86244.
118. Koch M, Matteo BD, Eichhorn J, Zellner J, Mayr F, Krutsch W. *et al.* Intra-ligamentary autologous conditioned plasma and healing response to treat partial ACL ruptures. *Arch Orthop Trauma Surg* 2018;**138**:675–83. https://doi.org/10.1007/s00402-018-2885-1.
119. Koch M, Mayr F, Achenbach L, Krutsch W, Lang S, Hilber F. *et al.* Partial anterior cruciate ligament ruptures: advantages by intraligament autologous conditioned plasma injection and healing response technique-midterm outcome evaluation. *Biomed Res Int* 2018;**2018**:1–9. https://doi.org/10.1155/2018/3204869.
120. Seijas R, Ares O, Cuscó X, Alvarez P, Steinbacher G, Cugat R. Partial anterior cruciate ligament tears treated with intraligamentary plasma rich in growth factors. *World J Orthop* 2014;**5**:373–8. https://doi.org/10.5312/wjo.v5.i3.373.
121. Kon E, Di Matteo B, Altomare D, Iacono F, Kurpyakov A, Lychagin A. *et al.* Biologic agents to optimize outcomes following ACL repair and reconstruction: a systematic review of clinical evidence. *J Orthop Res* 2022;**40**:10–28. https://doi.org/10.1002/jor.25011.
122. Murray MM, Spindler KP, Abreu E, Muller JA, Nedder A, Kelly M. *et al.* Collagen-platelet rich plasma hydrogel enhances primary repair of the porcine anterior cruciate ligament. *J Orthop Res* 2007;**25**:81–91. https://doi.org/10.1002/jor.20282.
123. Murray MM, Spindler KP, Devin C, Snyder BS, Muller J, Takahashi M. *et al.* Use of a collagen-platelet rich plasma scaffold to stimulate healing of a central defect in the canine ACL. *J Orthop Res* 2006;**24**:820–30. https://doi.org/10.1002/jor.20073.
124. Glyn-Jones S, Palmer AJ, Agricola R, Price AJ, Vincent TL, Weinans H. *et al.* Osteoarthritis. *Lancet* 2015;**386**:376–87. https://doi.org/10.1016/S0140-6736(14)60802-3.
125. Fithian DC, Paxton EW, Stone ML, Luetzow WF, Csintalan RP, Phelan D. *et al.* Prospective trial of a treatment algorithm for the management of the anterior cruciate ligament-injured knee. *Am J Sports Med* 2005;**33**:335–46. https://doi.org/10.1177/0363546504269590.
126. Meuffels DE, Favejee MM, Vissers MM, Heijboer MP, Reijman M, Verhaar JA. Ten year follow-up study comparing conservative versus operative treatment of anterior cruciate ligament ruptures. A matched-pair analysis of high level athletes. *Br J Sports Med* 2009;**43**:347–51.
127. Neuman P, Englund M, Kostogiannis I, Fridén T, Roos H, Dahlberg LE. Prevalence of tibiofemoral osteoarthritis 15 years after nonoperative treatment of anterior cruciate ligament injury: a prospective cohort study. *Am J Sports Med* 2008;**36**:1717–25. https://doi.org/10.1177/0363546508316770.
128. Murata K, Kanemura N, Kokubun T, Fujino T, Morishita Y, Onitsuka K. *et al.* Controlling joint instability delays the degeneration of articular cartilage in a rat model. *Osteoarthr Cartil* 2017;**25**:297–308. https://doi.org/10.1016/j.joca.2016.10.011.
129. Fleming BC, Carey JL, Spindler KP, Murray MM. Can suture repair of ACL transection restore normal anteroposterior laxity of the knee? An ex vivo study. *J Orthop Res* 2008;**26**:1500–5. https://doi.org/10.1002/jor.20690.
130. Murray MM, Fleming BC. Use of a bioactive scaffold to stimulate anterior cruciate ligament healing also minimizes posttraumatic osteoarthritis after surgery. *Am J Sports Med* 2013;**41**:1762–70. https://doi.org/10.1177/0363546513483446.
131. van der List JP, DiFelice GS. Role of tear location on outcomes of open primary repair of the anterior cruciate ligament: a systematic review of historical studies. *Knee* 2017;**24**:898–908. https://doi.org/10.1016/j.knee.2017.05.009.
132. van Eck CF, Limpisvasti O, ElAttrache NS. Is there a role for internal bracing and repair of the anterior cruciate ligament? A systematic literature review. *Am J Sports Med* 2018;**46**:2291–8. https://doi.org/10.1177/0363546517717956.

133. DiFelice GS, van der List JP. Clinical outcomes of arthroscopic primary repair of proximal anterior cruciate ligament tears are maintained at mid-term follow-up. *Arthroscopy* 2018;**34**:1085–93. https://doi.org/10.1016/j.arthro.2017.10.028.
134. Hoffmann C, Friederichs J, von Rüden C, Schaller C, Bühren V, Moessmer C. Primary single suture anchor re-fixation of anterior cruciate ligament proximal avulsion tears leads to good functional mid-term results: a preliminary study in 12 patients. *J Orthop Surg Res* 2017;**12**:171. https://doi.org/10.1186/s13018-017-0678-9.
135. Krismer AM, Gousopoulos L, Kohl S, Ateschrang A, Kohlhof H, Ahmad SS. Factors influencing the success of anterior cruciate ligament repair with dynamic intraligamentary stabilisation. *Knee Surg Sports Traumatol Arthrosc* 2017;**25**:3923–8. https://doi.org/10.1007/s00167-017-4445-6.
136. Mukhopadhyay R, Shah N, Vakta R, Bhatt J. ACL femoral avulsion repair using suture pull-out technique: a case series of thirteen patients. *Chin J Traumatol* 2018;**21**:352–5. https://doi.org/10.1016/j.cjtee.2018.07.001.
137. Ateschrang A, Schreiner AJ, Ahmad SS, Schröter S, Hirschmann MT, Körner D. *et al*. Improved results of ACL primary repair in one-part tears with intact synovial coverage. *Knee Surg Sports Traumatol Arthrosc* 2019;**27**:37–43. https://doi.org/10.1007/s00167-018-5199-5.
138. Webster KE. Editorial Commentary: anterior cruciate ligament suture repair could have high failure rates in active athletes of all ages. *Arthroscopy* 2021;**37**:1202–3. https://doi.org/10.1016/j.arthro.2021.01.054.
139. Büchler L, Regli D, Evangelopoulos DS, Bieri K, Ahmad SS, Krismer A. *et al*. Functional recovery following primary ACL repair with dynamic intraligamentary stabilization. *Knee* 2016;**23**:549–53. https://doi.org/10.1016/j.knee.2016.01.012.
140. Hourston GJM, Kankam HKN, McDonnell SM. A systematic review of anterior cruciate ligament primary repair rehabilitation. *J Clin Orthopaed Trauma* 2022;**25**:101774. https://doi.org/10.1016/j.jcot.2022.101774.
141. Wu J, Kator JL, Zarro M, Leong NL. Rehabilitation principles to consider for anterior cruciate ligament repair. *Sports Health* 2022;**14**:424–32. https://doi.org/10.1177/19417381211032949.
142. Vermeijden HD, Yang XA, van der List JP, DiFelice GS. Large variation in indications, preferred surgical technique and rehabilitation protocol for primary anterior cruciate ligament repair: a survey among ESSKA members. *Knee Surg Sports Traumatol Arthrosc* 2020;**28**:3613–21. https://doi.org/10.1007/s00167-020-06011-7.
143. Bousquet BA, O'Brien L, Singleton S, Beggs M. Post-operative criterion based rehabilitation of ACL repairs: a clinical COMMENTARY. *Int J Sports Phys Ther* 2018;**13**:293–305. https://doi.org/10.26603/ijspt20180293.
144. Costa-Paz M, Ayerza MA, Tanoira I, Astoul J, Muscolo DL. Spontaneous healing in complete ACL ruptures: a clinical and MRI study. *Clin Orthop Relat Res* 2012;**470**:979–85. https://doi.org/10.1007/s11999-011-1933-8.
145. Vavken P, Murray MM. The potential for primary repair of the ACL. *Sports Med Arthrosc Rev* 2011;**19**:44–9. https://doi.org/10.1097/JSA.0b013e3182095e5d.
146. van der List JP, DiFelice GS. Successful arthroscopic primary repair of a chronic anterior cruciate ligament tear 11 years following injury. *HSS J* 2017;**13**:90–5. https://doi.org/10.1007/s11420-016-9530-8.


*Burns & Trauma*, 2025, 13, tkae079
https://doi.org/10.1093/burnst/tkae079
Guideline