

Review

Anterior cruciate ligament repair with internal brace augmentation: A systematic review



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ABSTRACT

Background: Primary repair of anterior cruciate ligament (ACL) ruptures has re-emerged as a treatment option for proximal tears, with internal brace augmentation often utilised. The aim of this study is to provide an overview of the current evidence presenting outcomes of ACL repair with internal bracing to assess the safety and efficacy of this technique.

Methods: All studies reporting outcomes of arthroscopic primary repair of proximal ACL tears, augmented with internal bracing from 2014–2021 were included. Primary outcome was failure rate and secondary outcomes were subjective patient reported outcome measures (PROMs) and objective assessment of anteroposterior knee laxity.

Results: Nine studies were included, consisting of 347 patients, mean age 32.5 years, mean minimum follow up 2 years. There were 36 failures (10.4%, CI 7.4% - 14.1%). PROMs reporting was variable across studies. KOOS, Lysholm and IKDC scores were most frequently used with mean scores > 87%. The mean Tegner and Marx scores at follow-up were 6.1 and 7.8 respectively. The mean side to side difference measured for anteroposterior knee laxity was 1.2mm.

Conclusions: This systematic review with meta-analysis shows that ACL repair with internal bracing is a safe technique for treatment of proximal ruptures, with a failure rate of 10.4%. Subjective scores and clinical laxity testing also revealed satisfactory results. This suggests that ACL repair with internal bracing should be considered as an alternative to ACL reconstruction for acute proximal tears, with the potential benefits of retained native tissue and proprioception, as well as negating the need for graft harvest.

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1. Introduction

Anterior cruciate ligament (ACL) reconstruction is currently the gold standard surgical treatment for ACL tears but has variable success rates in term of patient satisfaction and revision rates of around 10-15% [1–3]. Realisation of the limitations associated with ACL reconstruction has prompted renewed interest into other techniques which could improve outcomes after ACL rupture. Modern arthroscopic surgical instrumentation has made repair of ACL tissue easier and advancements in functional tissue engineering and regenerative medicine have resulted in a revival of ACL repair [4,5]. Theoretically, this technique could restore normal patient anatomy, retaining proprioceptive fibres, whilst not causing donor site morbidity [6].

Outcomes following early ACL repair surgeries in the 1970s may have been confounded by the surgical technique used, which included both a large arthrotomy and extensive postoperative cast immobilisation, both of which are the opposite of the fundamental principles of modern ACL surgery, which focuses on early range of motion and accelerated rehabilitation [7,8].

The arterial blood supply to the ACL is from a web-like network within the synovial membrane, with the greatest density proximally and relatively poor vascularity in the middle and distal third of the ligament [9]. Furthermore, a recent study [10] found that the vascularity was significantly increased in a torn ACL compared to intact ligaments, adding evidence to support the potential for ACL healing. Sherman highlighted a subgroup of patients from his early ACL repair cohort who had acute, proximal ACL tears with excellent tissue quality who did well following ACL repair [11]. DiFelice and colleagues have proposed in several of their studies that proximal based tears of the ACL should be the focus when selecting patients for primary repair [12–21].

Murray et al [22] have postulated that ACL healing can occur as long as mechanical homeostasis can be achieved to allow a stable fibrin-platelet scaffold to form at the injury site. This can be achieved using an additional scaffold such as a mechanical augment. Three main ACL repair techniques have been developed aiming to improve the mechanical environment, namely, Bridge Enhanced ACL Repair (BEAR) [23], Dynamic Intraligamentary Stabilisation (DIS) [24] and internal brace ligament augmentation (IBLA) [25,26]. BEAR is a biologically enhanced scaffold used to treat midsubstance tears. DIS has been used with increasing prevalence in Europe but results have shown high re-operation rates particularly due to hardware irritation [27–29]. Internal bracing is the augmentation of a ligament repair with high strength suture tape, which reinforces the ligament and acts as a secondary stabiliser [25]. This promotes natural healing of the repaired proximal ACL tear by protecting it from excessive elongation during the early healing stages. The results from the only cohort of patients treated with ACL repair and internal bracing, with outcomes reported at five years, was recently published [30]. There have been several other authors reporting their outcomes in recent years, but to date no systematic review or meta-analysis specifically focusing on the technique of ACL repair with internal bracing. This systematic review with meta-analysis was therefore performed to assess the safety and efficacy of this technique. The aim is to provide an overview of the current evidence presenting outcomes of ACL repair with internal bracing.

2. Methods

2.1. Literature search

A literature search was performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines and the study was registered on PROSPERO (CRD42021267659). The search was conducted across the online databases, PubMed (Medline), Embase, and the Cochrane library. The search contained the keywords [“Anterior Cruciate Ligament” OR “ACL” AND “repair” AND “Internal Brace” OR “suture tape” OR “suture augmentation”]. Only English language articles were included and those published between 1st January 2014, and 1st July 2021. The start date was used as this is the time around which modern ACL repair methods began to be reported, with studies reporting on ACL repair prior to this generally using the open method rather than arthroscopic. Titles and abstracts of all identified records were reviewed, and the full text was reviewed for relevant articles by two authors, WW & GH. The reference lists of these articles were also reviewed, and any further potentially eligible studies were identified. As well as this, the ‘related articles’ function of PubMed was used to identify any further relevant publications. All studies reporting clinical outcomes of

proximal ACL tears treated with primary arthroscopic repair and internal brace augmentation were included. Animal studies, cadaver studies, those reporting outcomes of case reports and those with less than one year follow-up were excluded.

2.2. Quality of studies

Level of evidence was assessed using the adjusted Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence [31]. The methodological quality of the studies was estimated using the Methodological Index for Non-Randomised Studies (MINORS) instrument [32], utilising the first eight questions, specifically designed for assessing non-comparative studies.

2.3. Data extraction

Data were extracted from each study and collated in Excel 2017 (Microsoft Corp., Redmond, WA, USA). Information recorded included journal and year of publication, authors, number of patients, mean patient age, gender, length of follow-up (minimum and mean), delay from injury to surgery and baseline patient activity level (Tegner score). The primary outcome collected was the failure rate, defined by re-rupture or revision for symptomatic instability. Secondary outcomes were subjective patient reported outcomes measures (PROMs) and objective clinical assessment of knee laxity. The most reported PROMs that were considered in the analysis were the Knee Injury and Osteoarthritis Outcome Score (KOOS) [33], Lysholm score [34] and International Knee Documentation Committee (IKDC) subjective score [35]. The activity level

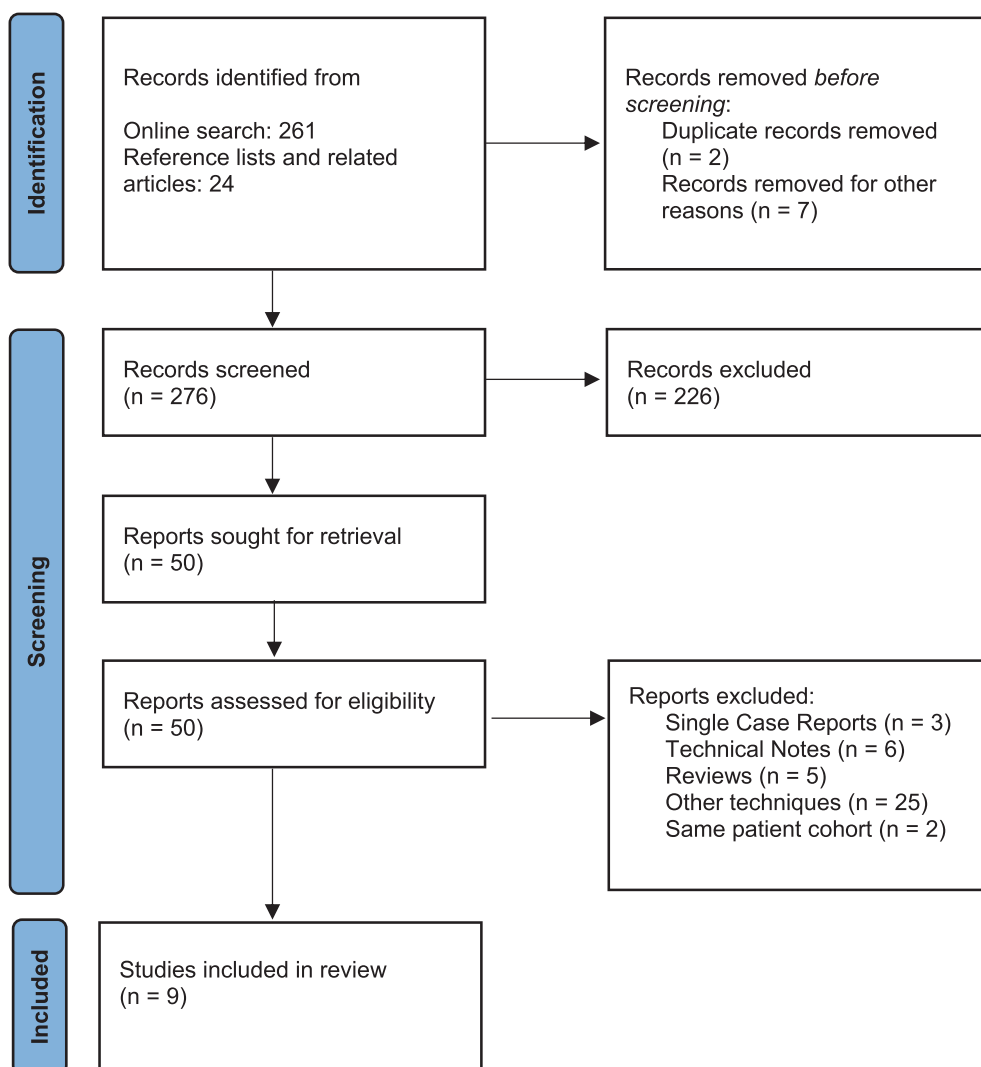


Fig. 1. Prisma Flowchart illustrating inclusion and exclusion of studies for review

of patients at follow-up was assessed using the Tegner activity scale [36] or Marx activity rating scale [37]. Objective laxity assessment was included if anteroposterior knee laxity was quantified using an instrumented method for Lachmann test.

2.4. Statistical analysis

Statistical analysis was performed using SPSS Statistics version 27.0 (SPSS Inc., Armonk, NY, USA). For each study the failure rate was calculated as the reported number of failures out of the total patient number in the study. These values were used to calculate 95% confidence intervals for each study. The overall failure rate was calculated as the harmonic mean; the total failures as a proportion of the total study population. Continuous variables were expressed as means \pm standard deviations. In the analysis, pooled outcomes were assessed by calculating weighted means by the sample size of each study as a proportion of the overall total patient number reporting that outcome.

3. Results

In total the search revealed 285 articles which were screened and full text reviews conducted for 50 following exclusions (Fig. 1). Eleven studies met the inclusion criteria, but two of these were reporting on the same group of patients as other included studies, at different time points [38,39]. Consequently, these two studies were excluded, and the two with longer follow-up retained, leaving nine overall which were included in the review [30,40–47].

There were no level one or two studies, three studies were level three [40,46,47], while the remainder (67%) were level four studies. The methodological quality of studies was assessed using the MINORS criteria, and the mean score was 10 out of 16 points (Table 1). No studies included blinding and two included comparisons with ACL reconstruction patients [40,46].

The meta-analysis consisted of 347 patients of which 161 (46%) were male. The mean age was 32.5 years, with a pre-injury Tegner activity score mean of 6.3. The mean minimum follow up was 2 years (range 1 – 5 years). There were a total of 36 failures out of 347 patients (10.4%, CI 7.4% - 14.1%, Table 2).

Postoperative complications that did not involve ACL re-rupture were only reported in one study [47]. Rates of re-operation, which was generally indicated for hardware irritation or subsequent meniscal injury were no different than in the reconstruction group considered in that study [47]. In the paediatric cohort presented by Dabis et al. [41], re-operation was considered standard care in all skeletally immature patients to release the internal brace at three months postoperatively.

Subjective PROMs reporting at final follow up was variable across studies with KOOS, Lysholm and IKDC scores the most frequently reported (Table 3). Lysholm score was utilised in five studies [40,41,43,45,47], KOOS in four studies [30,41,42,44] and IKDC subjective score in four studies [40,43,45,47]. Meta-analysis revealed mean scores greater than 87% of maximum for all three subjective PROMs. The mean Tegner and Marx scores at follow-up were 6.1 and 7.8 respectively. The mean pre-injury Tegner score for those reported was 6.3, demonstrating a small decrease in activity level from pre-injury to follow-up ($p < 0.001$). Of the four studies that reported both pre-injury and follow-up Tegner scores, two [43,45] showed equivalent scores and two [46,47] showed a decrease of less than one point at follow-up.

Anteroposterior (AP) knee laxity was quantified in four studies using KT-1000 [40,43], Rolimeter [45] or KiRa triaxial accelerometer [41]. The mean side to side difference in laxity for Lachmann test was 1.2mm.

4. Discussion

This systematic review found that nine studies have reported outcomes of ACL repair with internal bracing in a total of 347 patients. The mean failure rate was 10.4% at mean follow-up of 2.7 years postoperatively. This would suggest that the technique is safe for use in acute proximal ACL tears. The results should however be interpreted with caution, as the level of evidence is low with most results coming from uncontrolled case series. In addition, the risk of bias is high with a significant proportion of the patients coming from the institutions of the innovators [30,47]. It is clear that the technique is worthy of

Table 1
Summary of included studies with quality assessment of using the Methodological Index for Non-Randomized Studies (MINORS) criteria

Publication	Journal	Evidence Level	MINORS Score (16)
Gagliardi et al. 2019 [40]	Am J Sports Med	3	12
Ortmaier et al. 2020 [46]	Sportverletz.-Sportschaden	3	9
Douoguih et al. 2020 [42]	ASMAR	4	9
Schneider et al. 2020 [43]	J Clin Med	4	9
Dabis et al. 2020 [41]	KSSTA	4	10
Heusdens et al. 2020 [45]	KSSTA	4	11
Burton et al. 2021 [44]	Arthroscopy	4	9
Vermeijden et al. 2021 [47]	Arthroscopy	3	10
Hopper et al. 2021 [30]	KSSTA	4	11

Table 2

Summary of patient characteristics in each of included studies and reported failure rates following ACL repair with internal bracing. (Overall shows totals and weighted means/standard deviations for meta-analysis)

Publication	Sample Size (n)	Male (n)	Delay to surgery (days)	Tegner score pre-injury	Mean Age (Years)	Follow up mean (Years)	Follow up minimum (Years)	Failures (n)	Failure rate (%)	Failure 95% CI Low	Failure 95% CI High
Gagliardi et al. 2019 [40]	22	12	34		13.9	3.2	2.2	9	40.9	20.7	63.7
Ortmaier et al. 2020 [46]	24	8		5.7	34.0		1.0	0	0	0	14.3
Douoguih et al. 2020 [42]	27	18			27.4	2.8	2.0	4	14.8	0.9	24.3
Schneider et al. 2020 [43]	93	26	2	6.0	42.0	1.8	1.0	3	3.2	0.7	9.1
Dabis et al. 2020 [41]	20	8	45		12.9	2.7	2.4	0	0	0	11.9
Heusdens et al. 2020 [45]	35	17		6.0	32.8		2.0	4	11.4	3.2	26.7
Burton et al. 2021 [44]	29	21			32.2	2.8	2.0	2	6.9	0.8	22.8
Vermeijden et al. 2021 [47]	60	33	38	7.1	29.4	2.2	2.0	8	13.3	5.9	24.6
Hopper et al. 2021 [30]	37	18			37.8	5.7	5.0	6	16.2	6.2	32
Overall [n or mean (SD)]	347	161	21 (18)	6.3 (0.5)	32.5 (8.7)	2.7 (1.2)	2.0 (1.1)	36	10.4 (9.7)	3.6 (5.0)	22.3 (13.4)

Table 3

Secondary outcomes measures recorded in each study, including subjective PROMs and objective measurement of knee laxity. (Overall shows totals and weighted means/standard deviations for meta-analysis)

Publication	Sample Size (n)	KOOS	IKDC	Lysholm	Marx	Tegner	Lachmann Difference (mm)
Gagliardi et al. 2019 [40]	22		90.8	100			2.0
Ortmaier et al. 2020 [46]	24					5.3	
Douoguih et al. 2020 [42]	27	83.7			8.6		
Schneider et al. 2020 [43]	93		87.4	92.6		6	1.0
Dabis et al. 2020 [41]	20	96.5		95		7	1.2
Heusdens et al. 2020 [45]	35		85.3	86		6	1.0
Burton et al. 2021 [44]	29	84.3					
Vermeijden et al. 2021 [47]	60		91.3	92		6.2	
Hopper et al. 2021 [30]	37	88.5			7.3		
Overall [n or mean (SD)]	347	87.7 (4.6)	88.5 (2.2)	92.4 (3.5)	7.8 (0.6)	6.1 (0.4)	1.2 (0.3)

consideration and that further well designed randomised controlled trials are required in order to explore the outcomes more thoroughly. Indeed, proposals for randomised trials have been registered with published protocols [48,49].

Animal and human biomechanical studies have shown that adding an internal brace to a construct is stronger and may be useful in resisting re-injury while the ACL is healing [50–54]. Internal bracing has a crucial role in stabilising ACL repair at loads occurring during normal daily activity. The additional strength of the internal brace increases ultimate tensile strength and leads to reduced peak loads on the ACL repair construct, as well as restricting gap formation to below 3 mm at loads up to 350N [54].

There have been several review articles on ACL repair published in the past few years [7,55–65]. These have mainly consisted of patients treated with DIS, BEAR or primary repair without augmentation. The overall consensus in these reviews is in keeping with what we have found; that prospective studies comparing ACL repair with ACL reconstruction, with longer follow-up are needed. The majority of reviews highlight the promising results and suggest that from the current evidence ACL repair is a safe treatment option for acute ACL ruptures. None of the previous reviews have specifically focused on the treatment of proximal tears with repair and internal bracing. Nonetheless, the failure rate of 10.4% demonstrated in this study compares well with those previously published for ACL repair at mid term follow up, approximately 7–11% [65]. Compared to ACL reconstruction these rates are slightly higher than those quoted from registries, however two recent

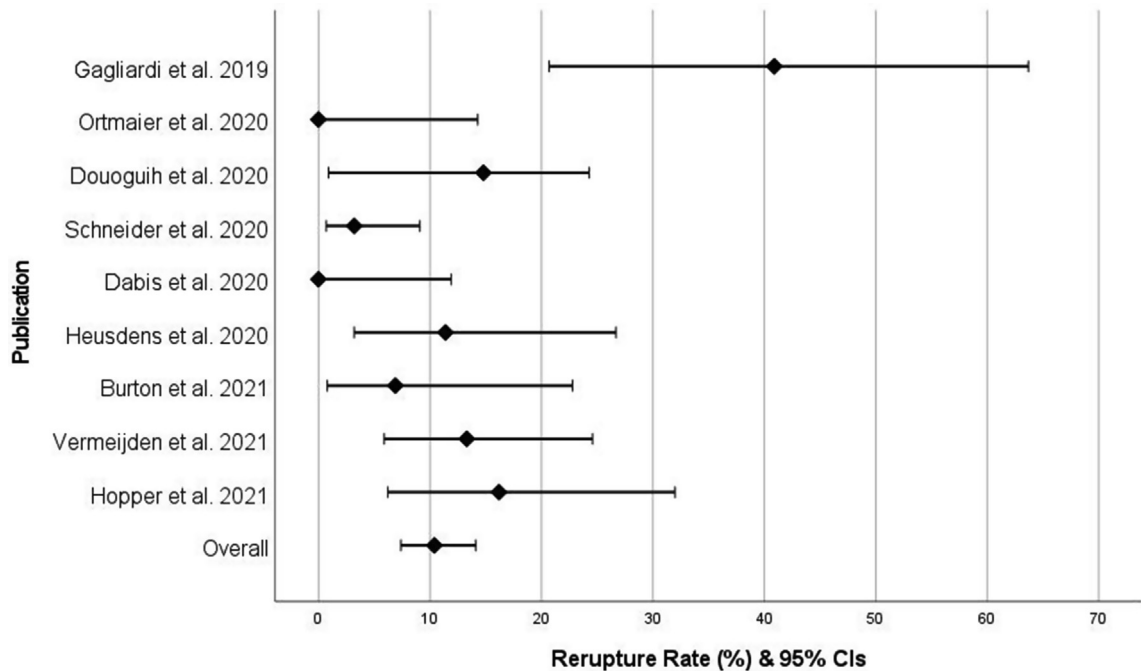


Fig. 2. Graph showing the failure rate of ACL repair with internal bracing for each study, rate in percent and 95% confidence intervals

meta-analyses showed an ipsilateral reinjury rate of 7% at 2 years, and up to 23% in patients who are younger than 25 years and returning to sport [66,67].

Fig. 2 shows the failure rates and confidence intervals for each study and all but one of the studies show similar results. Gagliardi et al. [40] demonstrated a high failure rate in 22 patients, aged 7–18 years compared to 157 ACL reconstructions. This rate is concerning, and out of keeping with the other studies in this analysis. Examining the detail of that study, there were only 22 patients in the repair group, a much smaller sample size than the reconstruction comparator group and also one of the smallest cohorts in this review. Also, both the mean age and the percentage of skeletally mature patients were higher in the reconstruction group (15.7 years and 58%, respectively) compared to the repair group (13.9 years and 32%, respectively). It is well documented that younger patients are significantly more likely to sustain a further ACL injury, making this group higher risk [68]. The 60% of this high risk population who underwent successful ACL repair, had no significant differences in return to sport rates, subjective PROMs or objective assessment compared to those who had reconstruction [40]. In contrast to Gagliardi et al [40], Dabis et al. [41] reported no failures in their cohort of 20 young patients, mean age 12.9, treated with primary repair with internal bracing at two years follow-up. Paediatric patients had previously been reported to have good outcomes from ACL repair in a small case series [69]. All patients demonstrated complete ACL healing at three months postoperatively, returned to activities at four months, and showed good objective outcomes at two years. Second look arthroscopy was carried out to remove the temporary internal brace to prevent growth arrest and confirmed healing in all cases [41,69]. Subsequent MRI confirmed a taut, healed and well-vascularised ACL in all patients [69].

The length of follow-up of the studies in this review was on average 2.7 years, with some only reporting one year follow-up. Only one study [30] reported outcomes at minimum five years postoperatively and the failure rate was 16%. It is worth noting that historic attempts at ACL repair using the open technique had demonstrated satisfactory outcomes at two years, but subsequently showed poor longer term outcomes, with around half of patients requiring revision surgery by five years [70–74]. It is encouraging that this trend has not been demonstrated in the five year outcomes that are available for this technique, but further longer term reports are awaited.

Whilst the choice of subjective PROMs scores used across the studies was variable, the results were similar for all outcome measures, with mean scores in excess of 87% of maximum. These figures are greater than those quoted as being the required threshold for a ‘patient acceptable symptom state’ following ACL reconstruction [75].

There was a small decrease in mean Tegner activity score from pre-injury levels. An overall decrease in the activity scores postoperatively has also been reported for patients undergoing ACL reconstruction [76,77].

Return to sport following ACL repair with internal bracing was examined in one study [46] where the authors matched 24 patients treated with ACL internal brace repair with

25 hamstring and 20 quadriceps tendon ACL reconstruction patients. At a minimum of one year follow-up, the overall return to sports rate was 91% with no significant differences in return to sports rate or time between the groups. These figures are a potential improvement on the reported rates from ACL reconstruction [78–80].

In the four studies that did report objective quantified measures of knee laxity [40,41,43,45], this technique was successful in preventing excessive anterior tibial translation, with a mean side to side difference overall of 1.2mm. Whilst this static stability is encouraging, further detailed functional testing to assess dynamic knee stability and the effect on knee kinematics and kinetics during functional tasks is required.

The results of this systematic review suggest that ACL repair with internal bracing is a safe treatment option as an alternative to ACL reconstruction in acute proximal tears, with acceptable failure rates and satisfactory outcomes. This would have the potential benefits of retained native anatomy with proprioceptive fibres and negating the risk of donor site morbidity during graft harvest. Furthermore, primary ACL reconstruction would be an option in the approximately 1 in 10 patients who do suffer failure of repair, and is a straightforward surgery in comparison to revision surgery for failed ACL reconstruction [81].

We recognise however that ACL repair technique is not suitable for all patients and careful patient selection is fundamental to the process. The studies included in this review report the results of patients with proximal tears, with midsubstance or distal tears probably best treated with other techniques. However, recent studies suggest that around half of patients have tears that are amenable to primary repair [14]. In addition, the mean time interval from injury to surgery reported in the meta-analysis was just 21 days, and we recognise that such a fast turnaround time may not always be possible in some healthcare structures, without significant organisational change. The longest time interval reported is six weeks post-injury, which might still be challenging to achieve in some scenarios. There are however no reports of attempted repair after a longer delay, although it is generally accepted that tissue quality and therefore reparability deteriorates with time.

Other factors which influence failure rate following ACL reconstruction are activity level and degree of laxity, in that high demand patients with gross pivot instability are higher risk. These patients have been found to benefit from an additional procedure to reconstruct or augment the anterolateral ligament (ALL) with a significant reduction in re-rupture rates [82,83]. This concept has also been utilised successfully with ACL repair and internal bracing and has the potential to significantly lower re-rupture rates in high risk patients [84].

5. Conclusion

This systematic review with meta-analysis shows that ACL repair with internal bracing is a safe technique for treatment of proximal ruptures, with a failure rate of 10.4%. Subjective scores and clinical laxity testing also revealed satisfactory results. This suggests that ACL repair with internal bracing should be considered as an alternative to ACL reconstruction in suitable cases, with the potential benefits of retained proprioception, as well as negating the need for graft harvest.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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