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REVIEW

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Are there any complications after lateral extra-articular tenodesis in anterior cruciate ligament reconstruction? – a systematic review

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Abstract

Introduction Lateral extra-articular tenodesis (LET) is a surgical technique that can be used in conjunction with anterior cruciate ligament reconstruction (ACLR), improving rotational stability and reducing the risk of anterior cruciate ligament (ACL) re-rupture. However, as with any surgical procedure, LET carries a risk of complications. Despite numerous articles published in recent decades discussing LET in the context of ACLR, relatively few complications associated with the LET procedure have been documented in the literature. This study aimed to systematically review adverse events associted with the LET procedure when combined with ACLR.

Material and methods The following key terms were used: (extra-articular OR extraarticular) AND (tenodesis OR plasty OR augmentation OR procedure or reconstruction OR reconstructive OR surgical OR surgery OR technique) AND (ACL OR anterior cruciate ligament), with no limits regarding the year of publication in PubMed, ScienceDirect, Cochrane Central, Web of Science, and Embase databases. English-language clinical human studies with evidence levels I-IV were included.

Results This analysis evaluated seven articles published between 1999 and 2023. Level IV evidence was identified in the majority of studies ($n=5$), level III evidence was found in one ($n=1$), and level I evidence was noted in another ($n=1$). Nine distinct types of complications were identified with rates rangingfrom 0.6% to 17% across the analysed studies. The modified Lemaire technique had the highest complication rate, reaching 7.5%. Overall, the complication rate across all reviewed LET techniques in this study was 4.2%.

Conclusion This is the first study to systematically document the occurrence of complications in LET. The most common problems included LET hardware irritation – predominantly after staple fixation, and subsequent removal, haematoma over the LET site, and pain over the LET site. The analysed studies show that combining LET with ACLR appears to be a safe procedure associated with infrequent and mild side effects.

Keywords LET complications, Lateral extra-articular tenodesis, Tenodesis, ACL reconstruction, Lateral knee ligaments, Lemaire technique

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Introduction

The anterior cruciate ligament (ACL) rupture is a common injury that leads to both anterior and rotational instability of the knee [5, 24]. The incidence of ACL tears has been reported to range from 30 to 81 cases per 100,000 individuals annually [39]. This injury is often accompanied by damage to other knee structures and increases the risk of meniscal tears and cartilage lesions, especially when surgery is delayed by 12 months or mores [16, 28, 40]. Arthroscopic ACL reconstruction (ACLR) is the first-line treatment for active individuals, aiming to improve knee function, eliminate instability, and prevent further intra-articular injuries [35, 36]. While standard ACLR techniques reduce anterior laxity, they do not fully restore anterolateral rotational stability of the knee joint. Moreover, it is estimated that at least 1 in 9 patients experience ACL re-rupture or clinical failure and 25% to 30% of patients continue to experience residual postoperative rotational instability [7, 33]. It is worth mentioning that while ACLR alone is intended to prevent accelerated knee arthritis, this issue remains a subject of debate. [29]

Lateral extra-articular tenodesis (LET) has regained increasing attention in recently as a surgical adjunct to ACLR. LET aims to restore the anterolateral soft tissue complex, which consists of the anterolateral ligament (ALL), the iliotibial band (ITB) with its the deep Kaplan fibre attachment to the capsule, as well as the menisci and the distal femur [30]. The combination of LET and ACLR aims to address rotational stability, prevent re-rupture of the reconstructed ACL, and facilitate a quicker return to sports [9, 32]. Historically, in 1879, Paul Ferdinand Segond described one of the components of the anterolateral complex, now known as the ALL, as a pearly band that reinforces the joint capsule and becomes extremely tensioned when the knee is forcefully rotated internally. LET procedure has been recognised since the 1960 s and was first described by Lemaire [4]. Initially recommended as a surgical treatment for ACL rupture, its clinical results were unsatisfactory when performed as a stand-alone procedure, leading to its abandonmentfor many years [13]. Currently, there are no definitive indications for LET; howeverthe following are generally accepted: patients with high-grade pivot shift, ligamentous laxity, those undergoing revision ACLR, high-demand young athletes and those requiring meniscus repair [15]. Various techniques are employed for LET, including the Lemaire technique, the MacIntosh procedure and its modification (Arnold and Cocker), the Ellison technique and others [38]. Although the specifics of these techniques vary, these procedures typically entail employing either synthetic materials or autografts to reinforce the knee's lateral structures [23]. Regardless of the kind of ACL autograft used, studies have shown that combining LET with ACLR reduces the risk of asymmetric pivot shift and protects against graft rupture [2, 14, 15]. However, like any surgical procedure, LET is not without complications. The possible peri- and postoperative complications following ACLR alone are diverse, and the total rate of complications differs between studies. Problems with hardware material, graft re-rupture, knee stiffness, infection, thromboembolic disease, arthrofibrosis, haemarthrosis, sensory loss and others are commonly described in the literature [10, 11, 19, 25].

Given the limited literature assessing complications associated with LET, the purpose of this study was to systematically review the complications described following LET when performed concurrently with ACLR. We hypothesized that the complications of LET would be diverse and partially linked with the concurrent ACLR.

Material and methods

Search strategy

An extensive search was conducted across major electronic databases (PubMed, Cochrane Central, ScienceDirect, Web of Science, and Embase) to identify all the essential studies that reported relevant information and data concerning the complications after LET in ACLR. This search was performed by three independent authors (*initials blinded for review*).

In November 2023, a systematic search was conducted using a combination of key terms: (extra-articular OR extraarticular) AND (tenodesis OR plasty OR augmentation OR procedure OR reconstruction OR reconstructive OR surgical OR surgery OR technique) AND (ACL OR anterior cruciate ligament), with no limits on the the year of publication. Moreover, an additional intensive search was conducted using the references of all identified studies. The collected literature was systematically reviewed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. (The PRISMA checklist for our project is presented in the Supplementary Material, along with PRISMA Flow Diagram in Fig. 1. This systematic review was registered in 2023 using the PROSPERO International Prospective Register of Systematic Reviews (registration number CRD42023428461).

Eligibility assessment

Screening of databases was carried out independently by three authors (*initials blinded for review*). Following the database search, three independent reviewers (*initials blinded for review*) screened all the papers to select

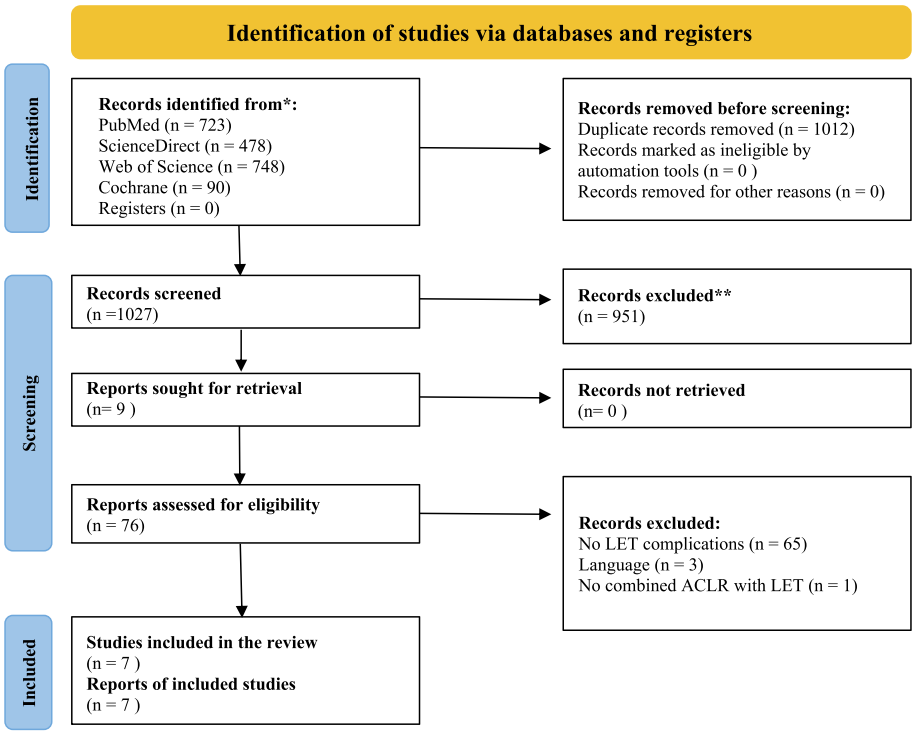

Fig. 1 The PRISMA Flow Diagram. * Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers). **If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools

titles, abstracts, and full texts relevant to LET in ACLR and complications after surgery. The inclusion criteria included: clinical human studies with levels of evidence I–IV, and publications in English language. Studies excluded from consideration were those in non-English languages, case studies, reviews, letters to editors, conference abstracts, or studies with incomplete or irrelevant data (level of evidence V). The exclusion criteria were as follows: any clinical outcomes and basic science studies involving joints other than the knee; anterolateral ligament studies; anatomic and radiographic studies; animal studies; editorial articles, and surveys. Papers without clearly described complications were also excluded. In case of disagreement among authors, the final decision was made by two senior authors and experts in evidence-based medicine (initials blinded for review).) made the final decision in case of disagreement among the authors.

Data extraction

Three independent reviewers (*initials blinded for review*) extracted the relevant data from the initially screened studies, including year of publication, country, type of study, number of subjects, surgical technique used, and complications after surgery.

Risk of bias assessment

The risk of bias assessment was performed using the Cochrane Collaboration's Risk of Bias Tool (supplementary material). Bias risk was classified as'low','high', or'unclear'for the following domains: sequence generation/allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective outcome reporting (reporting bias), and other sources of bias. Three reviewers independently assessed the papers' quality and reached a consensus.

Results

Of the 76 scientific publications identified during the'eligibility'stage, we extracted a subset of publications that exclusively addressed complications following LET surgery performed concurrently with ACLR. This subset comprised seven articles, representing 9.2% of the total publications. The general characteristics and demographic data are presented in Table 1. Most studies provided level IV evidence ($n = 5$); two of the remaining studies consisted of level III ($n = 1$) and level I ($n =$

Table 1 The general characteristics and demographic data of the included studies on the complications in the LET procedure

Authors	Study design	Level of evidence	Type of study	Number of described types of complications	Total number of complications	% of total complications relative to the number of patients	Number of patients with tenodesis	Observation period (months)	Mean age (years)	Number of revision
Meynard et al. [31]	Single-centre standard of care study	4	Retrospective	**1**	**3**	**6%**	**50**	**118,8**	**28,5**	**0**
Eggeling et al. [12]	Cohort study	3	Retrospective	**1**	**4**	**17%**	**23**	**28,7**	**33.3**	**23**
Ibrahim et al. [20]	Case series	4	Retrospective	**1**	**1**	**0.6%**	**153**	**70**	**23,7**	**0**
Feller et al. [13]	Case series	4	Retrospective	**1**	**1**	**4%**	**25**	**24**	**18,5**	**0**
Declercq et al. [8]	Case series	4	Retrospective	**1**	**1**	**1.1%**	**86**	**67,7**	**26,1**	**0**
P Imbert et al. [21]	Multicenter study	4	Retrospective	**2**	**14**	**2.9%**	**478**	**81,6**	**28,9**	**0**
M Heard et al. [18]	Randomized Clinical Trial	1	Prospective	**7**	**23**	**7.5%**	**306**	**24**	**19,1**	**0**

1) evidence. The majority of studies included were retrospective ($n=6$), with only one study being prospective ($n=1$). The total number of individuals included in the studies was 1121. Gender distribution was described as male-predominant accounting for 72.4% ($n=812$). The smallest number of patients who underwent the LET procedure was reported in the study by Eggeling et al., with a total of 23 patients. This was closely followed by the study by Feller et al., comprising 25 patients. In contrast, Imbert et al. documented the largest cohort, comprising 478 subjects. The average age of the participants across all studies was 25.4 years. While the mean ages were generally similar, the highest recorded mean age was 33.3 years in the study by Eggeling et al., and the lowest was 18.5 years in the study by Feller et al.

The follow-up period for patients following surgery, showed considerable variability cross studies. The mean observation time was 59.3 months. The shortest follow-up period was reported in two studies conducted by Feller et al. and Heard et al., both with a follow-up period of 24 months. In the remaining studies, the follow-up period for patients was longer than 24 months. The longest follow-up period was reported in the study by Meynard et al., in which patients were observed for 118.8 months. A slightly shorter follow-up period was reported in the study by Imbert et al., with a follow-up duration of 81.6 months.

The collected publications highlighted a variety of techniques for the LET procedure (Table 2). These included the modified Lemaire, MacIntosh, modified Ellison, modified Coker-Arnold, and a proprietary technique of one of the main orthopedic surgeon, which has been routinely used in their practice since 2004 [31]. Additionally, one technique was identified as unspecified by the authors of the publication [21]. Of the publications collected, three specifically noted the use of the Lemaire technique in patients scheduled for surgery, while each of the remaining techniques was used once. A revision procedure combining LET with ACLR was reported in only one study by Eggeling et al., involving 23 patients. A total of six study reports did not include any references to treatments involving ACL revision in conjunction with LET surgery.

The article identified nine types of complications. The range of complications rates in the analysed studies was 0.6%—17%. The study by Heard et al. demonstrated the highest number of complication types (7) as well as the largest total number of complications (23), although it did not specify the exact number of patients affected.. Imbert et al. presented two types of complications with a total number of 14 occurrences. The other studies each reported only one type of complication.

A review of the collected publications revealed that several complications directly associated with the LET

Table 2 Techniques used in particular studies

	Meynard et al. [31]	Eggeling et al. [12]	Ibrahim et al. [20]	Feller et al. [13]	Declercq et al. [8]	Imbert et al. [21]	Heard et al.18
Technique developed by one of the authors (S.C.—Stéphane Costes)	+	-	-	-	-	-	-
Modified Lemaire	-	+	-	-	+	-	+
MacIntosh	-	-	+	-	-	-	-
Modified Ellison	-	-	-	+	-	-	-
Modified Coker-Arnold	-	-	-	-	+	-	-
Unspecified technique	-	-	-	-	-	+	-

Table 3 Complications associated with the LET procedure

Complications	Number of papers	Authors
Removal or irritation of LET fixation material	3	M Heard et al., Meynard et al., Imbert et al
haematona over LET site	3	Heard et al., Ibrahim et al., Declercq et al
pain over LET site	2	Imbert et al., Eggeling et al
LET graft rupture intraoperatively	1	M Heard et al
IT band snapping	1	M Heard et al
over-constrained lateral compartment	1	M Heard et al
LET staple hardware failure intraoperatively	1	Heard et al
damage to fibular collateral ligament	1	Heard et al
LET soft tissue anchor and associated sutures local infection	1	Feller et al

procedure were documented in studies conducted by the aforementioned authors.

Table 3 presents an overview of complications directly related to the LET procedure. Two complications were identified as occurring with notable frequency, each appearing in three separate studies. Haematoma formation at the LET site was observed in patients from studies conducted by Heard et al., Ibrahim et al. and Declercq et al. Notably, the second most prevalent complication was irritation of the LET site due to hardware, which occasionally requiredremoval. This complication was observed in publications by Heard et al., Meynard et al. and Imbert et al. Another common complication of the LET procedure was pain over the LET site. This pain was observed in patients in two separate publications, namely those by Imbert et al. and Eggeling et al. Other complications observed included LET graft rupture intraoperatively, IT band snapping, over-constrained lateral compartment, intraoperative failure of LET staple hardware and damage to the fibular collateral ligament, which was observed exclusively in patients included in the study conducted by Heard et al. In the case of the publication by Feller et al., one patient exhibited a local infection resulting from the LET soft tissue anchor and associated sutures.

Table 4 presents an overview of complication rates associated with specific surgical techniques. The Modified Lemaire technique was performed on the largest number of patients ($n = 371$) and had the highest number of distinct complications types ($n = 8$) with a total of 25 complications, resulting in a complication rate of 7.5%. The second most frequently used method was the MacIntosh technique and was applied to 153 individuals and exhibited a complication rate of 0.6%. The remaining techniques were used on fewer patients, with complication rates of 4% for the modified Ellison technique, 0% for the Coker-Arnold technique, and 6% for the author's technique (S.C.—Stéphane Costes). Among 478 patients, the surgical technique was unspecified and a complication rate of 2.9% was noted. Overlal, the total complication rate across all surgical techniques was 4.2%.

Discussion

This systematic review aimed to identify and highlight complications associated with the LET procedure when performed alongside ACLR. With the increasing focus on LET procedures in the setting of concurrent ACLR in recent years, this is the first study that emphasizes the side effects of this intervention. The findings revealed that the most common and recurrent complications were removal or irritation of LET material fixation, haematoma over LET site and pain over LET site. The total complication rate across all LET methods was 4.2%.

The modified Lemaire, the modified Ellison, MacIntosh, the original technique (S.C.—Stéphane Costes) and the modified Coker-Arnold methods, are among the techniques that support the knee's lateral structures. Most of these techniques involve passing a graft (e.g. a strip of the iliotibial band) under the fibular collateral ligament [38]. Subsequently, a graft requires fixation to the bone using hardware, that depends on the surgeon's preference (sutures, anchors, staplers, screws and etc.),. Hardware irritation after the LET surgery was described in three publications [18, 21, 31]. Heard et al. noticed three cases of intraoperative LET staple hardware failure, which wereresolved with hardware exchange, while ten patients required postoperative removal of the LET staple. Despite the necessity of LET hardware removal, the overall rate of reoperation between isolated ACLR and ACLR + LET groups was similar (18% vs. 15% respectively) [18]. Meynard et al. observed discomfort related to the interference screw near Gerdy's tubercle in three individuals, but only one required screw removal [31]. Imbert et al. also noticed hardware irritation in their group of patients. This discomfort was localised to the area of the tenodesis attachment site and occurred in fourteen patients. In seven patients, the irritation it was transient, while in the remaining seven patients the symptoms were persistent and required either removal or burying

Table 4 Comparison of techniques with associated complication rates

	Number of patients treated with particular technique	Number of described types of complications	Total number of complications	Complication rate among patients treated with each particular technique
Original technique (S.C.—Stéphane Costes)	50	1	3	6%
Modified Lemaire	371	8	28	7.5%
MacIntosh	153	1	1	0.6%
Modified Ellison	25	1	1	4%
Modified Coker-Arnold	44	0	0	0%
Unspecified technique	478	2	14	2.9%

of the fixation hardware [21]. Fixation methods across the reviewed studies included sutures, anchors, staples and interference screws. The last two were particularly associated with irritation or the need for removal, which was observed after applying the modified Lemaire, Macintosh techniques or the original method (Stéphane Costes). On the contrary, Behrendt's study compared anchor and interference screw fixation in LET procedure and found no clinical difference at the 12-month follow-up [1]. In the case of isolated ACLR, hardware-related complications are rare and mainly involve screw migration, incomplete or accelerated material resorption and inflammatory reaction 10. Based on these findings, it can be concluded that addition of LET in ACLR may increase the incidence of hardware removal due to irritation.

The next most frequently observed complication was haematoma formation. Three publications reported the development of a haematoma in the area of LET procedure [8, 18, 20]. In the study of Ibrahim et al., only one patient suffered from a haematoma in the area of ALL that required incision and drainage [20]. It is worth mentioning that haematomas occurred in two studies where the Lemaire technique was used [8, 18] and in one study where the Macintosh technique was applied [20]. In contrast, when considering ACLR alone, haematomas are a rare complication, whereas haemarthrosis is more commonly observed and can often be prevented by using drainage for 24 h [34].

Pain is an indispensable element of any surgical intervention. The LET procedure serves as an adjunct to complex ACLR, which may additionally involve meniscectomies or meniscus suturing, potentially resulting in overlapping and increasing pain for some patients. Identifying the exact source of pain in such cases is challenging, especially considering that pain is a subjective experience [6]. This complexity is further amplified by the variety of questionnaires used to assess pain symptoms across different activities [37] Moreover, pain after first-time ACLR lone has been reported in 9–39% of patients [42]. For instance, Eggeling et al. found that 4 out of 23 patients complained about pain over the LET side during knee movements or resting. However, pain scores between the revision ACRL + LET group and the revision ACLR-alone group were not statistically significant [12]. The pain associated with the LET procedure is not only directly related to the procedure itself, but can also be caused by the hardware used and/or associated with an over-constraint of tibial rotation in the anterolateral structures of the knee [12, 21]. There are concerns that LET might lead to over-constraint of the lateral tibiofemoral compartment, potentially resulting inknee osteoarthritis. The follow-up duration in the studies included in this systematic review, ranges from 24 months to 118,8 months, what may impact the likelihood of detecting complications, especially osteoarthritis. However, studies with a 10-year follow-up have not shown an increase in osteoarthritis or stiffness after LET in combination with ACLR compared to ACLR alone [31]. Furthermore, Vigilietta et al. presented that after 15.7 years of follow-up, isolated ACLR was associated with higher osteoarthritis grades in the overall tibiofemoral joint and the lateral knee compartment than ACLR + LET, suggesting that addition of LET may provide a more stable knee function [41].

Despite following the rules of asepsis and antisepsis, infection can still occur. In the study by Feller et al., one patient experienced a recurrent local infection and required LET soft tissue anchor and sutures removed 10 weeks after surgery [13]. A septic arthritis of the knee one month postoperatively was reported by Declerq et al. [8] that required arthroscopic drainage and appropriate antibiotic therapy with good final results. However, it was not considered as a typical LET complication due to its extra-articular character, but rather associated with ACLR as a procedure on its own. It is also worth mentioning the other complications that occurred: iliotibial band snapping, fibular collateral ligament tear and overconstrained lateral compartment [18].

Although every surgical method is associated with minor or major complications, the addition of LET to ACLR seems to be associated primarily with mild or moderate side effects. The total complication rate of the LET procedure is reported to be 4.2%, which may be considered an acceptable outcome. For comparison, ACLR alone has a perioperative complication rate of 4.3% [26]. However, complication rates vary across different techniques, ranging from 0.0% to 7.5%, indicating viability in surgical safety. Each technique has distinct biomechanical properties and fixation methods, which could impact complication rates, especially if an unspecified technique was included, adding ambiguity. Only randomized controlled comparisons can determine whether the technique itself or other factors (e.g. patient selection, the hardware used, mean age) contribute to this variability. Furthermore, the complication rate of LET might be underestimated because only one randomized clinical trial was included, which typically follows stricter protocols compared to the rest of the cohort and retrospective studies. These arguments may explain why the modified Lemaire technique was associated with the highest complication rate. Firstly, this technique was applied to the largest number of patients, increasing the statistical power of the findings. Secondly, the majority of patients treated with this method were part of randomized

controlled trial. On the other hand, the benefits of LET appear to outweigh its potential side effect. The meta-analyses and systematic reviews, including only randomized controlled trials, indicate that both LET and ALL reconstruction procedures combined with ACLR are associated with lower graft failure rates, improved rotational knee stability and better patient-reported outcome measures [3]. Moreover, Grassi et al. presented that out of 2559 patients who underwent ACLR + LET surgery, only 58 (2.27%) required readmission. The main causes of rehospitalization included fever, knee swelling, superficial and deep infection, and joint stiffness [17]. The admission rate was comparable to results observed after isolated ACLR hospitals in New York State and the English National Health Service [22, 27]. These findings may indicate that adding LET procedure to ACLR does not increase the frequency of complications.

This systematic review was not without limitations. First, the methodologies of the included studies varied significantly, especially in terms of operative LET methods, hardware used, follow-up period, level of evidence and study designs.. The heterogeneity in study design may affect the strength and reliability of conclusions. Second, the literature on this topic is limited and most of the studies do not distinguish between complications arising from isolated ACLR and those from ACLR + LET. Moreover, the cause of some complications cannot be definitely attributed to either ACLR or ACLR + LET. Third, a source of selection bias was inherent, as only English language studies were included.

In summary, this systematic review has highlighted a few of the current complications and provided valuable insight into the state of LET in ACLR. To enhance the field it is recommended that future studies should aim for standardized LET procedures, conduct longer prospective follow-ups and implement uniform complication reporting. This will help to reduce heterogeneity and improve comparability between studies.

Conclusions

This is the first study to systematically identify and categorise the types of complications associated with LET and their occurrence. The most common issues were LET hardware irritation – predominantly following staple fixation, and subsequent removal, hematoma over the LET site, and pain over the LET site. Overall, the analysed studies show that adding LET to ACLR seems to be a safe procedure associated with rare and mild side effects. However, high heterogeneity among the studies highlights the need for additional high-quality studies to validate the findings.

Authors' contributions
J.Z., J.E., M.Z. formal analysis, resources, manuscript writing and editing; J.Z. and A.K. supervision, funding acquisition, critical revision of the article, and final approval; J.Z., J.E. manuscript writing and editing; A.K., Ł.Ł., S.M. critical revision of the article and finalapproval. All authors have read and agreed to the published version of the manuscript.

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Declarations

Ethics approval and consent to participate
Not applicable.

Competing interests
The authors declare no competing interests.

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