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Original Research

Review of Arthur E. Ellison's work on anterolateral rotatory laxity of the knee: The classic

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ABSTRACT

This classic discusses Arthur E. Ellison's (1926–2010) contributions to our understanding of anterolateral rotatory laxity of the knee. Ellison was a distinguished orthopaedic surgeon and one of the founding members of the American Orthopaedic Society for Sports Medicine (AOSSM). He served as the team physician for the United States ski team and Williamsburg football team. Ellison's publications focussed on the pathodynamics of knee stability, shedding light on the biomechanical functions of the iliotibial band. This led to the development of his lateral extra-articular procedure designed to control excessive tibial rotation in the anterior cruciate ligament (ACL) deficient knee. His work has made a significant contribution to our understanding of knee stability today, and many surgeons still use a modified version of Ellison's original technique to augment ACL reconstruction.

This article summarises Ellison's original publications and the first description of his operative technique. The impact of his work is discussed in the context of modern practice. The aim of this study is to add these valuable insights to the current discussion regarding the optimal method for lateral extra-articular tenodesis.

Level of evidence: V - Expert Opinion.

INTRODUCTION

The anterolateral ligament (ALL) of the knee has recently garnered significant attention for its role in controlling anterolateral rotatory laxity, since the publication of a detailed anatomical study by Claes et al. in 2013 [1]. However, the origin of this concept can be found as early as 1879, when it was first described by the renowned French surgeon Paul Segond (1851–1912) [2]. Segond noted that forceful rotation of the knee joint resulted in a distinct, intra-articular fracture of the lateral condyle of the tibia. At the fracture site, he observed the presence of a "pearly, resistant, fibrous band that is placed under extreme tension when the knee is forcefully rotated internally". This initial description of what we now recognise as the ALL established a foundation for the development of lateral knee, extra-articular procedures designed to control tibial rotation in the anterior cruciate ligament (ACL) deficient knee.

In modern clinical practice, lateral extra-articular tenodesis (LEAT) is typically used to augment intra-articular ACL reconstruction and has been shown to reduce rerupture rates in high-risk patients undergoing ACL reconstruction (ACLR) [3]. However, multiple techniques for LEAT have been described and there remains uncertainty about which procedure is most effective [4]. This study explores Arthur E. Ellison's original observations on anterolateral instability of the knee with the aim of contributing to the ongoing debate regarding the optimal method for augmenting ACL reconstruction.

CONSIDERATION

Historic perspective

The 1960's and 1970's saw a significant shift in the management of ACL injuries [5]. Previously, it was believed that the ACL did not contribute to knee stability and that surgical intervention was rarely indicated. Furthermore, diagnosing ACL injuries acutely was uncommon given the absence of magnetic resonance imaging (MRI) and the

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limitations of early arthroscopy. Therefore, chronic ACL deficiency was managed using LEAT in isolation, which was popular as an effective and less invasive alternative to open arthrotomy with ACL reconstruction [5].

There were several techniques for LEAT proposed during this era. Marcel Lemaire, a French surgeon, was one of the first to recognise the crucial role of the ACL in controlling knee rotation and stability, leading him to publish a description of his original LEAT procedure in 1967 [6,7]. Alternative techniques were described by several surgeons including MacIntosh and Losee, although few remain in use today [8–10].

Arthur E. Ellison also devised his technique for LEAT in the 1970's. Ellison was a surgeon from New England, USA, who was a member of the faculty at both the University of Massachusetts Medical School in Worcester, Massachusetts, and Albany Medical College in Albany, New York. He was one of the founding members of the American Orthopaedic Society for Sports Medicine (AOSSM). He had a keen interest in sports knee injuries, particularly in skiing, leading him to become the team physician for the USA ski team and the Williamsburg football team.

His technique was one of the first to use distal–as opposed to proximal–fixation of the iliotibial band (ITB) graft. Several surgeons still use a modified version of his original technique today. However, although his technique is used commonly in Australia [11], it has not yet gained international adaptation compared to other proximally based LEAT procedures. This may because of a relative paucity of literature on its use.

SUMMARY OF THIS CLASSIC

Arthur E. Ellison significantly advanced our understanding of anterolateral rotatory laxity of the knee, particularly in the context of anterior cruciate ligament (ACL) deficiency. Ellison was a surgeon from New England, USA, who was a member of the faculty at both the University of Massachusetts Medical School in Worcester, Massachusetts, and Albany Medical College in Albany, New York. He was one of the founding members of the American Orthopaedic Society for Sports Medicine (AOSSM). His work focused on the biomechanical role of the iliotibial band (ITB) in knee stability. This led to the development of his lateral extra-articular procedure designed to control excessive tibial rotation.

Ellison's procedure was notable for its use of distal fixation of the ITB graft, a departure from other methods that used proximal fixation. This approach allowed for "dynamic" stabilisation of the knee, with the ITB graft tightening as the knee extends and slackening as it flexes. This design aimed to control rotational movement without overly constraining the joint. It was initially used as a less invasive alternative to early intra-articular ACL reconstruction techniques. Despite its proposed benefits and published evidence of its good clinical outcomes, the technique has not gained widespread international adoption and is mainly used in Australia.

This article provides a comprehensive review of Ellison's original publications, detailing his surgical technique and the clinical outcomes of his procedure. It also discusses the evolution of the Ellison procedure in response to criticisms and its adaptation in modern practice. Ellison's work remains relevant today, as his knowledge of knee biomechanics continues to influence contemporary surgical techniques. By revisiting his foundational ideas that led to the design of his procedure, this article contributes to the ongoing debate regarding the best methods for managing anterolateral rotatory laxity in ACL-deficient knees.

Scientific and societal impact

Ellison's understanding of the pathodynamics of knee stability

Ellison's analogy for describing how to control knee rotation is practical and memorable. He considered the ACL to be *"located virtually at the axis or pivot of the knee and at the hub of the wheel"* [12]. Ellison believed this *"places it in a superb location to guide rotational movement but at a very disadvantageous position to restrict rotation"*. He, therefore, saw distinct advantages in stabilising the knee on the outside rather than reconstructing the ACL, based on his thinking that *"it is easier to control the rotation of a wheel at its rim than at its hub"* [12].

Throughout his work, Ellison highlights not only the ACL's role in rotational control but also its relationship with other structures in the knee, like the menisci and various ligaments, which he believed were also crucial for stability. He felt that anterolateral rotatory laxity developed from progressive weakening of the other ligaments in a knee that was already ACL deficient [12]. Ellison also believed that the ITB was the primary lateral stabiliser of the knee and could substitute for the ACL if positioned correctly [13].

Ellison devised a lateral extra-articular procedure that aimed to correct for knee instability by restraining the tibia and restoring balance between the medial and lateral compartments. He stated that *"stability can be restored by retaining the lateral tibial condyle posteriorly by transplanting the iliotibial band posteriorly, in a flexor position, thus preventing it from going into an anterior or subluxing position"*. He did this using "dynamic stabilisation" because he believed that dynamic transfers were less prone to stretching out and could provide greater constraint to the point of angulation than static stabilisers [13]. The most important advantage of Ellison's "dynamic stabilisation" is achieved by maintaining continuity and not anchoring the ITB proximally. This construct allows the ITB graft to tighten as the knee extends and slacken as the knee flexes. As a result, the tenodesis is most effective at lower flexion angles and in extension, where the pivot shift phenomenon occurs, while preventing excess knee tightness when the knee is in more flexed positions [14].

Ellison's original procedure

Ellison had the idea to turn the conventional proximally fixed tenodesis on its head and decided to fix the strip of ITB distally to Gerdy's tubercle. His rationale was to try to utilise the potential dynamism that the ITB offered by virtue of its attachment to the tensor fascia lata and gluteus maximus muscle [13,15]. Several studies highlight that his technique recreates close to normal kinematics in the anterolateral capsule while avoiding overconstraint of tibial internal rotation. Additionally, it has been shown not to increase lateral-compartment contact forces when compared with the modified Lemaire and modified MacIntosh procedures [14,16].

Ellison referred to the graft taken from the ITB as the "transplant". His surgical procedure began with the application of a tourniquet and placement of a bolster under the thigh, which allowed the knee to be placed into high flexion. An S-shaped incision was made, starting just above the lateral femoral condyle, extending along the knee's anterolateral surface to the edge of the patellar tendon.

Subcutaneous fat was then dissected to clearly define the iliotibial tract, which outlined the transplant area. A straight incision was executed along the superior border of the ITB, starting above Gerdy's tubercle and encircling it. Subsequently, a button of bone was lifted from Gerdy's tubercle, and a fascial strip that included the ITB was shaped, with its width adjusted according to the patient's size. This strip of ITB was fashioned to have a broad proximal base, reminiscent of an "Erlenmeyer flask", to preserve the maximum blood supply and maintain the dynamic pull of the muscles.

The anterior and posterior margins of the iliotibial tract were meticulously freed, which was crucial to allow for the proper closure of the defect.

The next step was to carefully pass a curved hemostat beneath the fibular collateral ligament, avoiding joint space penetration. The fibular collateral ligament was dissected up to its bony insertion on the femoral condyle to prevent the transplant from angulating on soft tissue and creating laxity. Plication of the mid-third capsular and arcuate ligament added extra stability, and the ITB was transferred distally beneath the fibular collateral ligament after all plications were completed (Fig. 1). Additional bone was removed from the proximal end of the tibia to create a trough that aligned with the pull of the transplant [Fig. 2].

The transplant was then secured with a staple and sutures to the patellar tendon and periosteum provided additional stabilisation [Fig. 3].

The iliotibial tract was meticulously closed over the transplant, forming a complete sleeve without directly suturing it to the transplant to

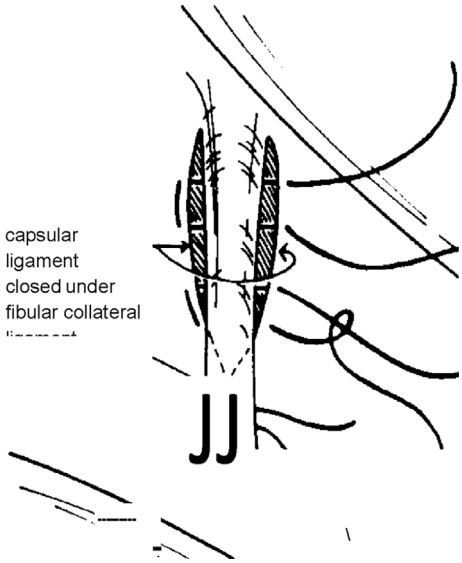

Fig. 1. The capsular ligament is reefed underneath the fibular collateral ligament. Reproduced with permission from Ellison AE, J Bone Joint Surg Am, 1979.

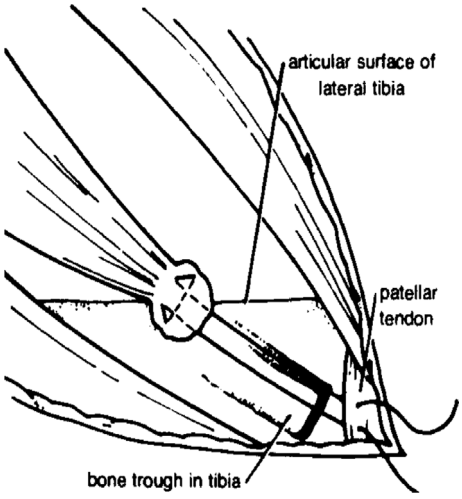

Fig. 2. A bone trough is prepared to receive the distal portion of the transplant. A suture is used to pass the button of bone just beneath the lateral fibres of the patellar tendon. Reproduced with permission from Ellison AE, J Bone Joint Surg Am, 1979.

allow free movement. Finally, the knee was immobilised in a long cast set at 60 degrees of flexion for six weeks, followed by a posterior, extension splint, and gentle hydrotherapy. During the early stages of convalescence, a Lenox Hill brace [Fig. 4] was used to protect the procedure and allow healing [13].

Current evidence as related to the original article

Initial results of Ellison's procedure

Ellison initially proposed his procedure as a less invasive alternative to early, primitive intra-articular ACL reconstruction techniques that could still effectively restore knee stability. In his 1979 article, along with outlining the steps of his procedure, he reports his patient outcomes for the first time. He described his immediate postoperative results and contrasted these with the outcomes observed at 2-years follow-up [13]. Patient outcomes were classified as excellent, good, or poor based on

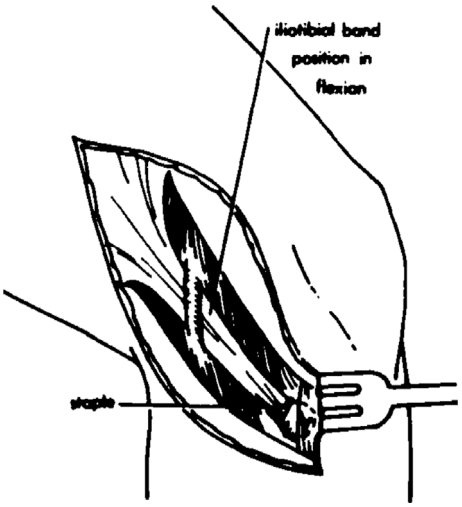

Fig. 3. The transplant has been anchored in its bone bed with a staple just proximal to the bone button on the transplant and a suture through the lateral fibres of the patellar tendon.

levels of activity, discomfort, and signs of knee instability. Postoperatively, 55.6% of the cases were deemed excellent, 27.8% good, and 16.6% were failures. Two years later, the excellent outcomes had slightly decreased to 44.4%, the proportion of good results increased to 39.0%, and the rate of failures remained unchanged at 16.6% [13].

Kennedy et al. challenged the benefits of the distally-fixed tenodesis in 1979. He suggested the proposed "dynamic stability" did not translate into improved clinical outcomes and that it's rotational control was insufficient. He reported the results of his assessment of 28 patients who underwent the Ellison procedure either in isolation or combined with a pes anserinus transfer to address posterolateral or anteromedial instability. He found that his outcomes were unpredictable and suggested that it should only be used as an adjunct to other procedures. However, it is crucial to consider that 14/28 of the patients had previously undergone an open total meniscectomy, and that all patients had chronic ACL deficiency, a context in which isolated LEAT is now understood to be ineffective [18–20].

In 1981, Hanks et al. reported their experience using the Ellison's procedure in isolation on 30 patients with ACL deficiency. They found that 79% of patients subjectively reported good results even though objective measurements measured 46% as "good". They only documented one "poor" outcome in a patient who returned to basketball "too soon" and one stretching out of the transfer. Their study highlighted that although the procedure seemed to be effective, certain patients developed varus instability and strength deficits at a mean follow-up of 25 months. That being said, they were unsure if this was functionally significant [21].

The long-term outcomes of 104 patients who underwent the Ellison procedure were first outlined in 1989 by Durkan et al. They reported data on 63 patients at a mean follow-up of 53 months. Postoperatively, 26% of patients subjectively indicated excellent outcomes with no pain or limitations, 54% reported good outcomes with occasional issues, 14% noted fair outcomes with moderate limitations, and 6% expressed poor outcomes with frequent pain and giving way [21]. Overall, the majority saw a reduction in episodes of knee instability postsurgery in addition to 81% showing improvement in their pivot shift. However, the procedure was less effective in patients with significant ligamentous laxity and in those with cartilage or meniscus damage. Furthermore, during the postoperative follow-up period, 14% of patients developed some varus laxity, and 15% of patients required additional surgery [22].

As intra-articular ACL reconstruction techniques developed, the Ellison extra-articular procedure was combined with other procedures. In 1986, Hoekstra et al. showcased a technique which they described as a

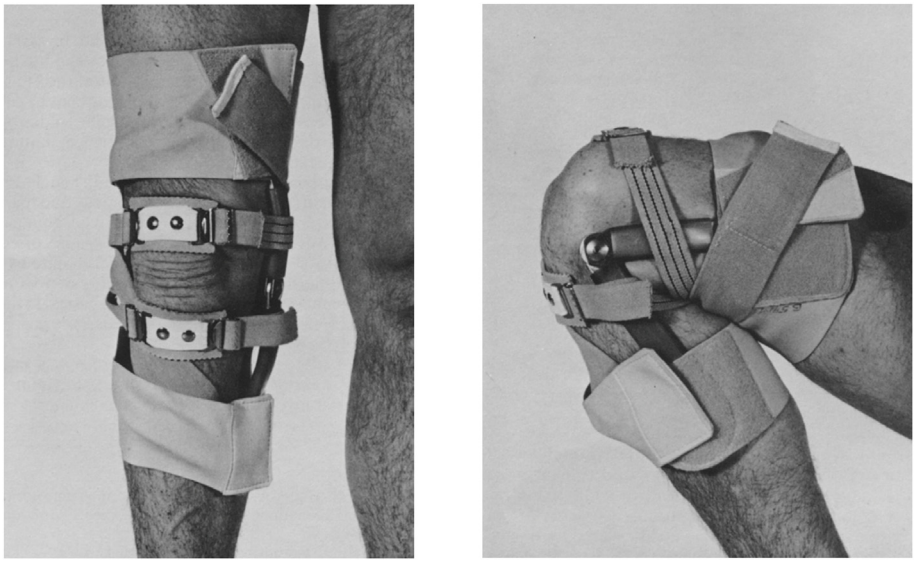

Fig. 4. (A): The Lennox Hill derotation brace in knee extension. **(B)** The Lennox Hill derotation brace in knee flexion. Reproduced with permission from Wellington P et al., Injury, 1984 [17].

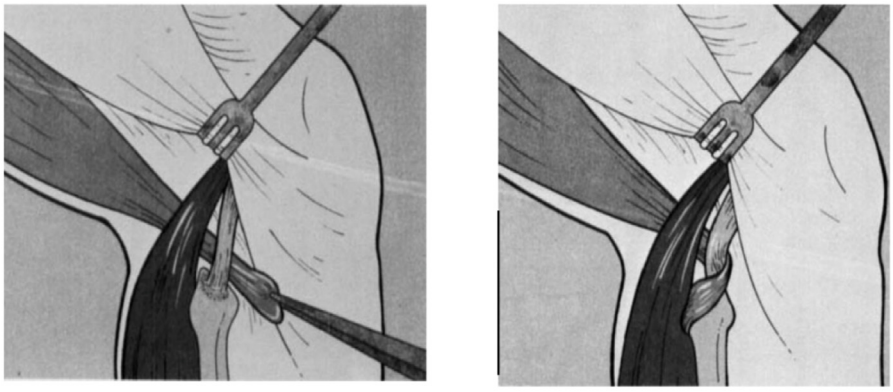

Fig. 5. (A): The biceps insertion is passed beneath the tendinous portion of the lateral head of the gastrocnemius and brought beneath the distal portion of the fibular collateral ligament under snug tension with the knee in a right angle position. **(B)**: The biceps tendon is then sutured to the capsule of the proximal posterior tibiofibular syndesmosis and the insertion of the arcuate ligament. It is also sutured to the distal portion of the fibular collateral ligament. Reproduced with permission from Ellison AE, Clin Orthop Relat Res., 1980.

combination of a dynamic and static reconstruction; the Erikson reconstruction-Ellison combination. They demonstrated its effectiveness in 27 athletes who could managed using a postoperative brace only without a cast. Of these 27 athletes, 22 reported being satisfied with the procedure despite some pain as a result of the staple or chondromalacia patellae. At 2 years follow-up, only 3 patients had subjective knee instability [23].

Biomechanical analysis of the Ellison procedure

Today, we have the benefit of modern biomechanical analyses that provide us with a more nuanced understanding of the effects of different LEAT procedures on tibial translation, internal rotation (IR), and anterolateral rotatory laxity (ALRL) during the pivot shift test [24,25]. To date, most studies have concentrated on proximally-fixed LEAT procedures to investigate concerns about potential knee overconstraint, which could result in lateral compartment osteoarthritis [4,26]. Although, the current best evidence does not support this hypothesis [27].

Notably, when biomechanical analysis of the distally-fixed Ellison procedure was conducted, it exhibited the pattern of restraint that Ellison theorised: that it closely restored native knee kinematics and only resulted in slight overconstraint of isolated IR in less than 30 degrees of flexion. Contrary to Ellison's belief, the same study found that closure of the ITB defect had no effect on knee kinematics [14].

Given the different effects each LEAT procedure has on the knee's kinematics, Neri et al. proposed the concept of tailoring the selection of the LEAT procedure to best suit a patient's distinct pathology [16]. They conducted an in-vitro biomechanical study comparing 5 different types of anterolateral procedures, using the full lower limb to ensure the dynamism of the ITB and biceps femoris were maintained. Their results demonstrated that only the modified Ellison procedure and ALL reconstruction effectively restored overall native knee kinematics in a combined ACL plus anterolateral-deficient knee. Additionally, the modified Ellison procedure significantly reduced internal rotation between 0° and 45° of knee flexion but did not provide rotational control beyond this range. On the other hand, the superficial and deep Lemaire and modified MacIntosh tenodeses provided additional control of IR but overconstrained knee kinematics which may suggest they are more suitable in the setting of revison ACLR [16].

The modified Ellison procedure

The first evolution of this technique was made by Ellison himself in response to Kennedy's concern about the limited constraining power of the procedure. He suggested it could be augmented by transferring the attachment site of the biceps femoris tendon [12]. This involved complete detachment of the bicep's distal insertion, rerouting it under the lateral collateral ligament and tendonous portion of the lateral

gastrocnemius before reinsertion to the proximal posterior tibiofibular syndesmosis and the insertion of the arcuate ligament [Fig. 5 (A,B)]. Ellison proposed this provided the requisite additional strength without jeopardising the iliotibial tract.

The modern, modified Ellison procedure incorporates several modifications while maintaining the fundamental principles of the original surgical technique [28]. A smaller incision is used and soft tissue dissection is minimised. In the description of the modified technique published by Feller et al. the patient is positioned with their leg at 60 degrees of flexion, and an incision is made from Gerdy's tubercle to 2 cm proximal to the LCL. A 10 mm ITB graft is harvested as in the original technique and passed deep to the LCL. Today, due to advancements in modern fixation techniques such as suture anchors, the requirement to reattach the graft to the lateral border of the patellar tendon with sutures has been eliminated [11,28].

Another difference to Ellison's original technique is that plication of the capsular and arcuate ligament to increase knee stability is done selectively. This is appropriate as the procedure is now carried out in the acute setting to augment ACLR as opposed to when there is a chronic, attenuated anterolateral complex. Other authors have suggested that closure of the ITB defect can be left to the surgeon's discretion as it avoids lateral patellofemoral overconstraint, although this is not yet supported by biomechanical data [28]. Furthermore, a biomechanical study has shown that, although closure of the defect may improve cosmesis by preventing muscle herniation, it does not alter the knee's kinematics [14]. Furthermore, contrary to the original procedure, which saw the patient immobilised for 6 weeks and splinted, the modern technique does not divert the ACLR rehabilitation protocol and permits immediate weightbearing and mobilisation [11].

The simplicity and efficiency of the procedure compared to other LEAT techniques makes the modified Ellison technique attractive. Additionally, it seems appropriate for skeletally immature patients, as it does not necessitate a fixation device near the distal femoral physis [29]. Contemporary results using this procedure have been demonstrated in a pilot study by Feller et al. who reported that only 1/25 patients (4%) experienced graft rupture after return to high-risk sport and that only one complication could be directly related to LEAT (local infection at the soft-tissue anchor site) [11].

Using a similar operative technique with slightly different postoperative instructions, Herbort et al. studied 36 patients with a mean age of 18.9 years managed using ACLR plus the modified Ellison procedure. In this cohort, 35 patients (97.2%) returned to their previous level of sport within 2 years. One patient suffered graft reinjury, one suffered a contralateral ACL injury, and two patients required resection of a cyclops lesion [30].

Lessons learned

By using distal fixation in lateral extra-articular tenodesis, Ellison's procedure maintains the dynamic function of the iliotibial band, allowing the graft to tighten during knee extension but slacken during flexion. This “dynamic” stabilisation effectively controls knee rotation as the knee approaches extension, while the release of tension during flexion prevents overconstraining the lateral compartment or limiting flexion. Contemporary clinical outcomes of the Ellison procedures have demonstrated low reinjury and complication rates, with the majority of athletes returning to their previous level of performance.

CONCLUSION

Today, a variety of techniques for LEAT exist, although it remains a topic of debate among surgeons as to which is the most effective. The legacy of Arthur E. Ellison in the realm of knee surgery is enduring. His original procedure, with its emphasis on dynamic stabilisation of the knee and the importance of viewing the anterolateral knee as a “system” with numerous parts, is relevant today.

Our hope is that by reflecting on these foundational ideas and by creating awareness about the effectiveness of Ellison's original procedure, we can help modern surgeons decide how best to manage anterolateral rotatory laxity.

Ethical approval

Ethical approval was not required for this article.

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Declaration of competing interest

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