The Classic

A review of Marcel Lemaire's original work on lateral extra-articular tenodesis

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ARTICLE INFO

Keywords:
- Lemaire procedure
- Lateral extra-articular tenodesis
- Anterolateral ligament
- Pivot shift
- Anterior cruciate ligament
- Iliotibial band

ABSTRACT

This classic discusses Marcel Lemaire's original publications in the context of modern surgical practice, including a description of his original lateral extra-articular tenodesis. Previously published in French, these translations shed light on his revelations regarding the anterior cruciate ligament's role in knee stability and his detailed insights into the ressaut rotaire or the pivot shift phenomenon. We track the evolution of Lemaire's procedure since the publication of his original technique in 1967 which used a nylon cord superficial to the lateral collateral ligament followed by cast immobilisation for one month. We report his patient outcomes as he refines his methods through experiential learning.

Lemaire's fundamental concepts in relation to anterior cruciate ligament deficiency remain relevant in contemporary clinical practice. Furthermore, the “modified Lemaire technique” has emerged as one of the preferred methods for lateral extra-articular tenodesis. We hope that disseminating his thoughts to a wider audience will help enlighten the ongoing debate regarding the management of rotatory instability.


BACKGROUND

Recently, there has been a renewed interest in using lateral extra-articular procedures to control excessive tibial rotation as a means of augmenting anterior cruciate ligament (ACL) reconstruction. Furthermore, despite advancements in intra-articular ACL reconstructive techniques, there is still a relatively high incidence of persistent anterolateral rotatory instability (ALRI) which has been associated with suboptimal outcomes [1,2].

The precise role and optimal surgical method for lateral extra-articular tenodesis (LEAT) remain subjects of considerable debate, leading to a variety of individual practices among surgeons. The “modified Lemaire technique” has emerged as one of the preferred procedures given its effectiveness in reducing the rate of ACL graft rupture in high-risk patient cohorts [3–6]. This technique was first proposed by Marcel Lemaire (1918–2006), a French gastrointestinal and thoracic surgeon who inadvertently established a reputation as an orthopaedic knee specialist. Although Lemaire had trained in general surgery, he was a keen footballer and had an interest in sports injuries. While playing for the Racing club de France, he was approached by the team president who proposed that he take on the role of team doctor. This is when Lemaire noticed the high incidence of meniscal tears among footballers and became fascinated by the unpredictability of outcomes after open meniscectomy. His interest in this field was nurtured under the mentorship of the renowned surgeon Albert Trillat from Lyon, who imparted his knowledge and techniques for operating on meniscal tears during their Monday golf sessions [7].

Lemaire published his seminal paper in Journal de Chirurgie (Paris) in 1967 outlining his observation that managing rotational laxity caused by ACL deficiency was paramount to controlling anterior translation. He noted that the persistence of the ressaut rotaire or the pivot shift – which he described as “the Lemaire sign” (unpublished) – consistently aligned with poor outcomes. In this paper, he also described his novel surgical technique for lateral extra-articular tenodesis [8]. His findings offered a novel perspective in an era before the availability of MRI and arthroscopy.

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https://doi.org/10.1016/j.jisako.2024.02.006
Received 16 December 2023; Received in revised form 1 February 2024; Accepted 20 February 2024
Available online 23 February 2024
2059-7754/© 2024 The Author(s). Published by Elsevier Inc. on behalf of International Society of Arthroscopy, Knee Surgery and Orthopedic Sports Medicine. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
However, Lemaire's original manuscripts were published in French and are not easily accessible to the English-speaking world. To address this, we have translated his work to allow dissemination of his crucial insights to a wider audience. Before reading these translations, it is important to contextualise the period when Lemaire worked. The writing style was much more verbose at the time and as such we have presented his work thematically, with excerpts of Lemaire's own writing. Evident from the papers included in this article, many publications were case series from individual hospitals and figures were generally hand-drawn, often in black and white due to the high costs of colour printing. Furthermore, methodologies were less thoroughly described and statistical analysis was rudimentary in comparison to today's techniques. Multi-centre collaboration was rare and articles were type-set, limiting their distribution primarily to academic meetings.

This manuscript follows Lemaire's publications in chronological order, beginning with his revelations regarding the ACL's role in knee stability and the significance of the pivot shift. We describe his original extra-articular procedure in 1967 and follow the evolution of his technique through his subsequent publications in 1980 and 1983 [9,10]. We also report his patient outcomes as his technique develops, while discussing the experiential learning he acquired throughout his career.

While delving into Lemaire's work, we found ourselves captivated by the timeless nature of his insights and the cyclical manner in which they once again become relevant. We hope that by reflecting on his ideas in the context of contemporary practice, we can enlighten the ongoing debate regarding the management of ALRI. In the words of Mark Twain: “There is no such thing as a new idea. It is impossible. We simply take a lot of old ideas and put them into a sort of mental kaleidoscope. We give them a turn and they make new and curious combinations. We keep on turning and making new combinations indefinitely; but they are the same old pieces of coloured glass that have been in use through all the ages.”

SUMMARY OF THIS CLASSIC

The “modified Lemaire technique” has become one of the preferred approaches for lateral extra-articular tenodesis. This article provides a translation of Marcel Lemaire's (1918–2006) original publications while discussing the relevance of his findings in the context of modern surgical practice. Despite training as a gastrointestinal and thoracic surgeon, Lemaire's interest in sports injuries led him to become the team doctor for the Racing club de France football team. Through this, he gained immense experience in knee surgery and shared his expertise in several papers, including his novel approach to lateral extra-articular tenodesis in the Journal de Chirurgie (Paris) in 1967.

Lemaire noticed that patients with an injured ACL experienced poorer outcomes after open meniscectomy. He deduced that the ligaments integral role in knee stability had been previously understated and advised that the ACL was routinely examined during meniscectomy. Additionally, he advocated for preservation of the meniscus whenever possible. Probably, his most notable contribution was his discovery of the ressaut rotatoire or pivot shift phenomenon, which he described as “the Lemaire sign” (unpublished). He recognised that it was not the persistence of anterior translation but of residual rotational laxity that impeded his patients returning to sport. His insights were foundational during a time before MRI and arthroscopy.

Lemaire's original technique for lateral extra-articular tenodesis used “un lacet de nylon” or a nylon cord to create a “neo-ligament” overlying the LCL. This was followed by a month of cast immobilisation. As he refined his technique through experience, he began passing the strip of fascia through a bone tunnel before looping it back to suture upon itself. This more robust method allowed his patients to start rehabilitation sooner. The outcomes of Lemaire's procedures were good with the majority of patients reporting satisfactory knee stability and return to sport. He highlighted several core surgical principles in his practice such as where to attach and the appropriate graft length when performing extra-articular ligamentoplasty.

THE ROLE OF THE ACL IN KNEE STABILITY

It is important to first consider the impetus behind Lemaire's research and the setting in which it took place. During the 1960s, it was widely upheld that acute ACL injuries infrequently required surgical intervention and that suture repair of the ACL was only indicated for severe instability or chronic ACL deficiency [11]. However, Lemaire noticed that certain patients experienced poor results after meniscectomy without any apparent reason. This prompted him to recognise the crucial role of the ACL in knee stability and the importance of controlling tibial rotation.

“One over many years of treatment of various sporting injuries, we have been surprised by the frequency of mediocre results for meniscectomy, even when carried out under optimal conditions and for real meniscal tears. These mediocre results often occur in young subjects where the injuries are not generally very old, where the knee is not usually affected by arthritis, and who rehabilitate well, and thus where all elements theoretically combine to obtain the best results. Several years ago, Robert Judet wrote that “20% of athletes could not, after meniscectomy, resume their normal sporting activity.” It is widely agreed that resuming normal sporting activity occurs when an individual is able to resume their normal and favourite sporting activity after the intervention, but also when they can practice it with the same possibilities as before the injury, both in the quality of their game and the duration of their career.

In contrast, for the great majority of athletes who undergo meniscectomy, that at first sight do not appear to be any different from those above in terms of the meniscal lesions observed during surgery or in the course of rehabilitation, their normal sporting potential is easily and rapidly restored and they have a knee that is apparently intact after long years of activity.

It appeared logical to us that this difference in evolution is not due to chance but is due to the presence of a coexisting lesion. In this context, we systematically verified the state of the anterior cruciate ligament (ACL) during all meniscectomies. The figures published on the frequency of the coexistence of two lesions are very variable. We observed, in our last 150 meniscectomies (since we systematically verified the state of the ACL) 44 complete ruptures of the ACL (a frequency of 28%).

This frequent association of a meniscal tear with a rupture of the ACL seems to explain the poor results of meniscectomies. Among subjects with an intact ACL, and if we exclude cases where we observed significant arthritis during surgery, the results of meniscectomy are perfect and nothing will delay recovery or reduce the sporting potential of the athlete.

It is well-known that, under optimum conditions of muscular rehabilitation in particular, ruptures of the ACL are well tolerated. However, it seems that this tolerance has been overestimated and that in fact athletes who retain their normal sporting potential are a lot rarer than generally believed.

Clinically, in a previously traumatised knee, a ruptured meniscus combined with a ruptured ACL is often difficult to affirm because the symptoms of the two lesions overlap, merge and cannot be differentiated. It is necessary to specify the exact circumstances of the injury, because it appears that ruptures of the ACL most often occur due to the knee unexpectedly giving way during external rotation of the body, with the foot remaining planted to the ground; this creates forced internal rotation of the tibia on the femur. Unfortunately, and often, injured subjects do not analyse their accidents in detail.”

Lemaire suggested that ACL injuries often went undetected during meniscectomy. He contended that previously, the implications of ACL deficiency on knee stability and patient outcomes weren't fully comprehended. These observations set the foundation for his research into controlling tibial rotation. It is also clear from this excerpt that during this time the ACL was not routinely assessed during open meniscectomy leading to Lemaire's recommendation “if the ACL lesion is associated with a
meniscal tear, it is necessary to start with meniscectomy and then to systematic check the state of the ACL. In the absence of a meniscal tear, and faced with doubtful clinical symptoms, the subject should be examined under general anaesthesia and, if doubt persists, a small arthroscopy should be performed enabling the ligament to be seen."

CLINICAL EXAMINATION: THE PIVOT SHIFT AND ANTERIOR DRAWER TEST

One of the most influential observations made by Lemaire, was his description of the ressaut rotatoire. Often credited with the discovery of the pivot shift phenomenon, Galway and MacIntosh later acknowledged that Lemaire’s description of a dynamic test in internal rotation was a similar manoeuvre [12]. In an era prior to the advent of MRI and widespread use of arthroscopy, clinical examination findings held greater significance and subtle observations were crucial for differentiating diagnostically guiding patient management.

“On examination, a large positive anterior drawer is not always present as this requires coexisting lesions. In this regard, we wish to report an observation that appears to be particularly interesting. One sign, which unfortunately is found only occasionally, seemed to us to be pathognomonic of ACL lesions: this is the possibility of triggering anterior-medial subluxation of the knee at the end of extension. We place the foot in internal rotation, with the knee extended. If we obtain complete muscular relaxation we can sometimes provoke, by pushing lightly on the head of the fibula and by making small movements in flexion-extension, anterior-medial subluxation. In these movements, by acting very gently, a ‘clunk’ occurs at the start of flexion where the injured person recognises a familiar accident. Unfortunately, this sign is quite difficult to find, because it requires complete muscle relaxation which is difficult to obtain. When investigated under general anaesthesia, this sign appeared to be very accurate but was not found clearly in all cases. However, when it is found it can confirm a rupture of the ACL.”

“In my practice, only two clinical signs are used to study the ACL: the anterior drawer test, which does not depend exclusively on the ACL (it is investigated at 60° of flexion and in minimal external rotation), and the pivot shift test, used since 1964 and a pathognomonic sign of a ruptured ACL.”

In his 1967 paper, Lemaire provides an anecdotal account of a soccer player who to his surprise could only return to sport briefly despite the disappearance of antero-posterior translation after treatment by cast immobilisation for 45 days. He uses this example to emphasise that the ligament’s poor healing and re-rupture rates of 50% at 5 years, focus shifted to reconstructive techniques such as Jones’ patellar tendon method [16,17]. Extra-articular ligamentoplasty remained popular as an effective treatment for chronic ruptures because it was significantly less invasive and less morbid compared to open arthroscopy. It also avoided the risks associated with reconstruction: flexion contracture, patellar fracture and immobilisation for 45 days [10,18]. In the descriptions of his surgical techniques, Lemaire also emphasised the importance of preserving the meniscus as much as possible.

“All evidence points to ligamentoplasty using the normal insertions of the ACL as the ideal solution. Unfortunately, no matter what material used to date, it is absolutely impossible to construct a decent ACL. In practice, by carrying out this intervention, the surgeon abandons the search for a faithful copy of the ACL and does nothing more than insert a band limiting abnormal laxity, which can be performed more easily and more simply by other operations. The other interventions proposed to repair a ruptured ACL have the double merit of being extra-articular and easy to perform.

Certainly, the meniscuses should be spared as much as possible: leave a tear in place that does not appear to have spread and is not easily accessible by arthroscopy. I think that meniscectomy on an unstable knee should be avoided absolutely without, at the same time, stabilising the joint.”

In the early 1980s, Dandy used an arthroscope, originally designed for meniscal tears, to perform the first arthroscopic ACL reconstruction [19]. The refinement of interference screw fixation further increased reliability of intra-articular ACL reconstruction, diminishing the need for extra-articular procedures [20,21]. In 1989, extra-articular procedures were abandoned in the United States after the AOSSM published a consensus that they were not beneficial and concerns were raised about potential post-operative stiffness and late osteoarthritis [22]. Today, the role for LEAT is being re-evaluated. Moreover, it has been proposed once again as an isolated procedure for older patients when ACL reconstruction is not indicated [23].

LEMAIRE’S ORIGINAL EXTRA-ARTICULAR TENODESIS

Lemaire’s first technique proposed in 1967 used “un lacet de nylon” or a nylon cord, overlying the LCL to create a new ligament. Postoperatively patients were placed in a plaster cast for one month with mobility restrictions to ensure proper ligament healing [8].

“The oblique cutaneous incision is made in a posterosuperior direction from Gerdy’s tubercle to the posterosuperior surface of the condyle. It follows the posterior edge of Maitiat’s band (iliotibial band). The aponeurosis is incised along the edge of the band which is often ill-defined. By a parallel incision 1.5 cm further forwards, joining the previous one to the posterior surface of the condyle, we detach the aponeurotic band which is strongly attached to the tubercle (Fig. 1). We displace it downwards and detach it from the upper part of the tubercle with a scalpel so as to make space away from the synovial membrane insertion and free the area intended for graft fixation. One must avoid using this segment of band alone due to its probable lack of strength.

In relation to the top of the incision, we search for the upper part of the LCL. Although it is usually easy to find, it may sometimes be more difficult, particularly in muscular individuals, under thick fibrous elements. However, to identify the ligament with certainty is, in our opinion, the most
critical part of the operation and the only time where we can commit an irreparable error. We follow the ligament to its upper insertion and it is at this precise insertion, as on Gerdy's tubercle, a hole is made, penetrating the bone cortex (Fig. 2). Once everything is prepared, we take a nylon cord which will constitute the solid element of the new ligament.

One end is inserted in the lower hole and a solid nylon thread in a U shape is used to fix the band to the fascia lata and periosteum (Fig. 3). A thin nylon suture is used to stitch one edge of the fibrous band of fascia lata to the other in order to create a channel where the nylon cord can move freely (Fig. 4). The end of this, chosen in order to keep an excess of around 2 cm, is inserted in the upper hole. A nylon thread attached to the cord in a U shape is attached above and in front of the hole. This thread is tightened progressively putting the cord under tension and the surplus is gradually inserted into the bone hole (Fig. 5).

There is no fear of overtightening it so that the natural elasticity of the nylon cord is lost. In forced movements very mild elasticity persists which is favourable and is why we prefer to always use a nylon cord rather than a more rigid material.

The only thing that remains is to cut the fibrous sheath of the band of fascia lata to the length required and to attach it with several nylon stitches to the perimeter of the hole. It is tightened without any special precautions because its role is secondary. If the tissues are supple enough and come together easily, we place several stitches on the capsule-Maissiat band; if they are not supple enough this procedure is pointless.

Finally, we put the patient in a full-leg bivalved plaster cast, prepared in advance. This helps avoid the risk, during application of the plaster, of movements of complete extension, which will exert strong traction on the loaded threads. The plaster is left in place for 1 month.
While describing his original surgical technique in 1967, Lemaire also outlined his fundamental surgical principles [8]. He emphasised the importance of positioning the graft at an oblique angle that allows maximal graft tension when the knee is at 150°. The critical point of joint stability while ensuring it does not restrict knee extension. He insisted that the upper graft insertion point should coincide with the upper insertion of the LCL. He believed that this was the location where nature intended, dictated by the complexity of the knee's flexion—extension axis and the intricate anatomy of the lateral femoral condyle. Lemaire noted that positioning the graft behind the LCL insertion restricts deep flexion, while placing it in front of the LCL insertion, limits flexion to 110°. He also noted that the optimal lower graft insertion point serendipitously coincides with Gerdy's tubercle, conveniently simplifying the surgical technique. Regarding graft length, he advised it was not too short as to restrict flexion but of adequate length to enable the knee to surpass the delicate 110-degree flexion point. It is also interesting to see how the emergence of modern synthetic materials used as internal bracing for ligament reconstruction mirror Lemaire's innovations using Nylon chord and represent another historical cycle of medical innovation.

THE EVOLUTION OF LEMAIRÉ'S PROCEDURE

Lemaire published updated technical descriptions of his procedure as it evolved "Over the years, it has been improved progressively with experience acquired during 2000 operations. Little by little, the strength of the reconstructed ligament has been increased, this is a better guarantee of the quality of the results." In his 1980 paper, he details his experimentation with operating on patients in the lateral decubitus position with the leg in maximal external rotation. The skin incision was 15 cm long starting at Gerdy's tubercle and curving to the upper insertion of the LCL. The fascia lata graft was also 15 cm long and 1.5 cm wide. An osseous tunnel was created using two drill holes and the graft is passed through the bone, now deep to the LCL. The graft was sutured to periosteum at the tunnel exit and then looped back to its starting point at Gerdy's tubercle, where it was also sutured to itself at maximum tension. The increased strength of fixation allowed immediate rehabilitation and mobilisation [9]. (Fig. 7).

Between 1980 and 1983, he gradually increased the restrictions on his patient's post-operative activities. Initially, patients could walk with aids on day 2 and return to sport in 6 weeks. However, as his approach evolved, patients were required to avoid standing/walking for 15 days and were not permitted return to sport for 2–3 months. Additionally, Lemaire introduced supplementary procedures such as posteromedial and antero-medial plasty to augment his lateral procedure. These procedures were used to address "medial capsule-periosteum tears" and patients with these injuries were identified based on his clinical exam findings. He noted that these procedures were often required in female patients, hyper-lax patients and those who wished to return to competitive sports [10].

In France, the modification of the Lemaire technique to a shorter graft was popularised by Christel et al. [23] Instead of looping the graft back to its origin, it is twisted 180° to maximise isometry and fixed to the femur using a screw or staple. The most cited “modified Lemaire technique” is published by Jesani et al. and uses a significantly shorter incision (6 cm vs. 15 cm) and smaller graft size compared to the original (8 x 1 cm vs. 15 x 1.5 cm). This technique still passes the graft deep to LCL and loops it back to its origin but has the benefit of new femoral fixation methods such as staples [18].

INITIAL RESULTS OF LEMAIRÉ'S PROCEDURE

It is believed that Lemaire first utilised his technique in 1960 on a dancer forced to abandon her career due to knee instability. This procedure enabled her to return to dancing. His first published results appear in his seminal paper in 1967, where he reports the outcomes of 46
patients with ACL insufficiency. Forty-four of these patients had an associated meniscal tear. Within this subgroup, 26 were highly active individuals, predominantly football players. Twenty-three chose surgical intervention, with 14 reporting excellent outcomes and resuming normal sports activity. Three others had good results with a slight decrease in their sporting performance. The 3 non-surgical patients in this subgroup universally ceased their sporting activities. Among the remaining 18 primarily sedentary patients, 13 underwent surgery. Ten reported a return to a normal knee function while the non-surgical patients had mixed results, with two returning to request surgery due to significant daily life hindrance. Lemaire concluded that while the results were not perfect, his technique obtained satisfactory results in 28/30 patients who underwent meniscectomy with a co-existing ACL rupture, who would have normally had a poor outcome [8].

In 1975, he studied 328 of his patients and demonstrated that 87% had good results. Despite recognising the procedure’s limitation in reducing the anterior drawer, Lemaire noted that it could eliminate the pivot shift, which in clinical practice appeared to be sufficient to enable patients to resume sporting activities. He concluded that “the great technical facility of operations of musculo-aponeurotic transposition, has led surgeons to discard plastic operations on the ligaments. They do, however, give the best chance of return to sporting activity” [24].

Lemaire subsequently published the functional outcomes of 156 patients who underwent extra-articular tenodesis between 1977 and 1981. An additional 59 patients responded to a questionnaire with 76% reporting significant satisfaction, aligning with his observation that 75% of athlete respondents maintained the same competitive level four years post-operation. Combining both groups, only a single patient declared their situation had worsened as a result of surgery. He found that almost universally, a slight anterior drawer persisted even with the disappearance of pivot shift. His main conclusion was that persistence of pivot shift indicated intervention failure and corresponded with poor functional outcomes, while loss of extreme flexion was common but had negligible functional impact (Fig. 6 (A, B)) [10].

Throughout his work, Lemaire also published specific case examples that highlighted key principles that he had learnt through experience. One case from his 1967 paper describes a player who injured his knee and had to leave the pitch because his knee was giving way. When examined he had 2 cm anterior translation of the tibia on drawer testing, a painless pivot shift and mild tenderness at the lower attachment of his
MCL. Lemaire notes that at this time, “the dogma of immediate surgery of ACL ruptures was not established and the technique was poorly defined” so the patient was immobilised in a cast for 45 days. The patient made a satisfactory recovery and following treatment, anterior-posterior mobility on the injured side was only slightly greater than the healthy side so it was assumed the ligament had healed. After physiotherapy, the patient returned to sport at a slightly reduced level but subsequently twisted his knee, tearing his medial meniscus. He underwent medial meniscectomy with creation of a new lateral ligament to compensate for his ACL deficiency and returned to sport with good function. Lemaire reports this case to highlight that disappearance of the anterior drawer sign is not sufficient to confirm ligament healing and that in the absence of this sign, he finds great diagnostic value assessing for moderate laxity in high knee flexion (>90°).

CONCLUSION

Today, there are a multitude of variations in approaches to LEAT with surgeons across the globe continuously debating the optimal graft length, placement and fixation method. Nonetheless, the modified Lemaire technique remains one of the most popular, as demonstrated by its selection for the STABILITY I and II randomised controlled trials [4,25,26].

Many of Lemaire’s original insights still resonate with current surgical practice and perhaps reflecting on his foundational observations will guide the orthopaedic community towards a more cohesive consensus on the optimal method for LEAT.

Declaration of conflicting interest

The authors have no conflicts of interest to declare.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical approval

Ethical approval was not required for this article.

Acknowledgements

N/A.

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