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Augmentation of Primary ACL Reconstruction With a Modified Ellison Lateral Extra-articular Tenodesis in High-Risk Patients

A Pilot Study

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Background: Lateral extra-articular tenodesis (LET) has been used to augment primary anterior cruciate ligament (ACL) reconstruction to reduce the risk of reinjury. Most LET procedures result in a construct that is fixed to both the femur and the tibia. In a modified Ellison procedure, the construct is only fixed distally, reducing the risk of inadvertently overconstraining the lateral compartment.

Purpose: To evaluate the use of the modified Ellison procedure in a cohort of patients deemed to be at a high risk of further ACL injury after primary ACL reconstruction.

Study Design: Case series; Level of evidence, 4.

Methods: Included were 25 consecutive patients with at least 2 of the following risk factors: age <20 years at the time of surgery, previous contralateral ACL reconstruction, positive family history of ACL rupture (parent or sibling), generalized ligamentous laxity (Beighton ≥4), grade 3 pivot shift in the consulting room, a desire to return to a pivoting sport, and an elite or professional status. All patients underwent primary ACL reconstruction with an additional modified Ellison procedure. Postoperatively, patients completed the IKDC subjective knee evaluation form (International Knee Documentation Committee), KOOS Quality of Life subscale (Knee injury and Osteoarthritis Outcome Score), ACL–Return to Sport After Injury Scale, Marx Activity Rating Scale, and SANE score (Single Assessment Numeric Evaluation).

Results: At 12-month follow-up, the mean outcome scores were as follows: SANE, 94/100; IKDC, 92/100; Marx, 13/16; ACL–Return to Sport, 85/100; and KOOS, 77/100. At 24 months, return-to-sport data were available for 23 of 25 patients; 17 (74%) were playing at the same level or higher than preinjury and 2 at a lower level. One patient (4%) sustained a contact mechanism graft rupture at 12 months. There were 2 (9%) contralateral ACL injuries, including 1 ACL graft rupture, at 11 and 22 months postoperatively. There was a further contralateral ACL graft rupture at 26 months.

Conclusion: The use of the modified Ellison procedure as a LET augmentation of a primary ACL reconstruction to produce a low graft rupture rate appeared to be safe in a cohort considered to be at a high risk of reinjury. The procedure showed promise in terms of reducing further graft injuries.

Keywords: knee; anterior cruciate ligament; reconstruction; lateral extra-articular tenodesis; graft rupture; return to sport

Lateral extra-articular tenodesis (LET) procedures have long been used in the setting of anterior cruciate ligament (ACL) injury and insufficiency, either as a stand-alone procedure or as an augmentation of both primary and revision ACL reconstruction procedures. The outcomes were poor when a LET was performed as an isolated stabilization procedure,[28] but when used as an augmentation of an intra-articular ACL reconstruction, LET has been associated with a reduction in the pivot shift, particularly in the setting of a delayed primary ACL reconstruction.[3,10,30] There has been a recent resurgence of interest in the role of the anterolateral structures of the knee in contributing to anterolateral rotatory stability of the knee. In response to this, the Anterolateral Complex Consensus Group suggested some possible indications for a LET procedure as an augmentation of an ACL reconstruction.[8] These included young patients returning to pivoting activities, a group known to be at high risk of further ACL

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injury.[17,18,20,29,32,34] In 2 recent studies of young patients who had undergone ACL reconstruction with a hamstring tendon graft, the addition of an additional LET reduced graft rupture rates (4%) when compared with patients who had a hamstring tendon graft in isolation (11%).[31,9]

In the randomized STABILITY Study, the LET procedure was a modification of procedures previously described by both Lemaire[15] and MacIntosh.[1] Like most LET procedures, it used a strip of iliotibial band (ITB), which was left attached distally to the Gerdy tubercle and fixed proximally to the femur in the region of the attachment to the lateral collateral ligament (LCL).[9] In 1979, Ellison[7] described a different approach to LET. He took a strip of ITB from the Gerdy tubercle, reflected it proximally, and then passed it distally and deep to the LCL to be reattached to the tibia anterior to the Gerdy tubercle. In addition, he described plication of the joint capsule deep to the LCL and closure of the ITB defect. This has several potential benefits over other LET procedures. Because the ITB is not fixed to femur, it is not dependent on the angle of knee flexion, the rotation of the tibia, or the tension applied to the strip of ITB at the time of fixation.

One modification of the original Ellison procedure involves not advancing the attachment of the strip of ITB, not plicating the capsule, and leaving the defect in the ITB open.[5] This modification has been examined biomechanically in a cadaveric model and was shown to closely restore knee laxities to native values in a knee in which an extensive anterolateral complex injury was simulated by sectioning the anterolateral capsule.[5]

From 2015 onward, in response to increasing data about the risk of ACL graft rupture in young patients,[17,34] the treating surgeon (J.A.F.) started to use a modified Lemaire/MacIntosh LET procedure with a primary ACL reconstruction in patients thought to be at a very high risk of graft rupture. In light of laboratory evidence regarding the effectiveness of a modified Ellison procedure,[5] in April 2017, the surgeon changed to a modified Ellison procedure, having frequently used this procedure in the setting of revision ACL reconstruction.

The purpose of this pilot study was to describe the modified Ellison procedure in detail and evaluate its use in an initial cohort of patients deemed to be at a high risk of further ACL injury after primary ACL reconstruction.

METHODS

All data-collection procedures were approved by hospital and university ethics committees. Between April 2017 and December 2018, a total of 25 patients underwent primary ACL reconstruction with an additional modified Ellison procedure. All surgical procedures were performed by a single experienced knee surgeon (J.A.F.) at a metropolitan private hospital. During this period, the same surgeon performed a further 260 primary ACL reconstructions without additional ligament surgery.

The patients who underwent the modified Ellison procedure were judged to be at a particularly high risk of graft rupture because they had at least 2 of the following risk factors: age younger than 20 years at the time of surgery, previous contralateral ACL reconstruction, positive family history of ACL rupture (parent or sibling), generalized ligamentous laxity (Beighton $\geq$4), grade 3 pivot shift in the consulting room, a desire to return to a pivoting sport, and an elite or professional status. The decision to perform additional surgery was made semiformally rather than by strict adherence to an algorithm and was made in consultation with the patient after discussion about the risk of reinjury.

Surgical Technique

ACL Reconstruction. The ACL reconstruction surgery was performed arthroscopically using either a hamstring tendon graft (doubled semitendinosus and doubled gracilis; n = 11) or a partial-thickness soft tissue quadriceps tendon graft (n = 14). Graft selection was made by the patients and, in the case of minors, their families after discussion of graft options with the treating surgeon. Quadriceps tendon grafts were not used in skeletally immature patients because of concerns that the patellar periosteum may be included in the graft construct, which might put the proximal tibial or distal femoral physes at risk of premature closure. The femoral tunnel was drilled to the proximal graft diameter via the anteromedial portal, with the tunnel centered in the footprint of the anteromedial fibers of the ACL. Similarly, the tibial tunnel was drilled to the distal diameter of the graft and centered in the tibial footprint of the ACL. After graft insertion, the knee was taken through 10 cycles of flexion and extension with traction applied to the distal end of the graft, before tibial fixation with the knee at 0° of knee flexion and with 44 N applied to the trailing ends of the whipstitch. For all graft types, suspensory fixation was used on the femoral side (EndoButton with a No. 5 and a No. 2 Ethibond whipstitch for quadriceps tendon grafts and EndoButton CL Ultra for hamstring tendon grafts). The distal end of the graft was secured with a No. 5 Ethibond whipstitch, and tibial fixation was by means of a metallic interference screw (Arthrex), unless the tibial growth plate was still open, in which case fixation was by

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Ethical approval for this study was obtained from La Trobe University (No. S16-500).

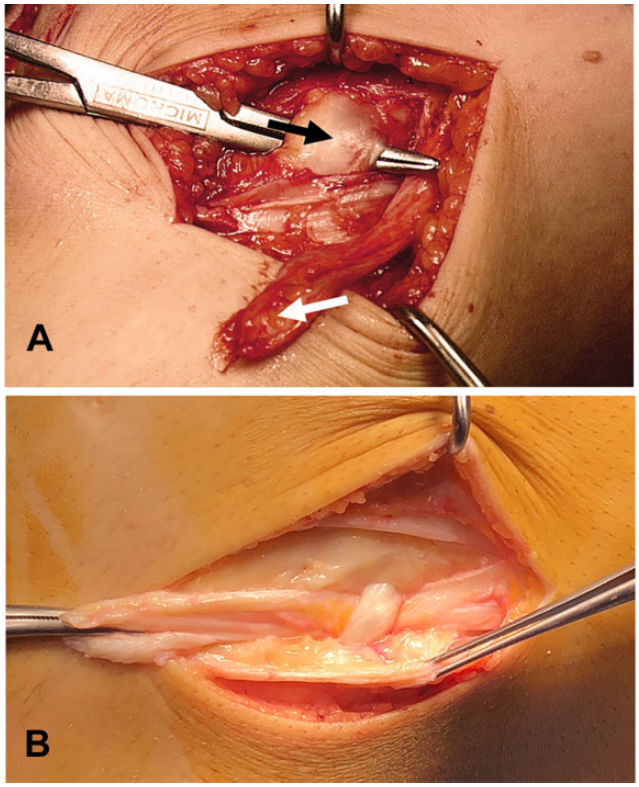


Figure 1. Left knee. (A) Strip of ITB has been mobilized (white arrow) and LCL exposed (black arrow). (B) Strip of ITB has been passed deep to LCL from proximal to distal. ITB, iliotibial band; LCL, lateral collateral ligament.

means of the whipstitch tied to a fixation post (Acufex; n = 2, both hamstring tendon grafts).

Modified Ellison Procedure. With the patient supine and the knee flexed to approximately 60° of flexion, an incision was made along the line of the ITB in a proximal direction from the Gerdy tubercle to 1 to 2 cm (depending on the patient's body habitus) proximal to the posterior margin of the LCL. The ITB was then exposed, identifying its anterior and posterior borders. The ITB was incised 10 mm anterior and parallel to its posterior border, commencing distally at the Gerdy tubercle and extending proximally to 2 cm proximal to the LCL. A second parallel incision was made 10 mm anterior to the first to develop a strip of ITB. At the Gerdy tubercle, the strip of ITB was sharply detached from the bone. The ITB strip was mobilized and reflected proximally with preservation of the Kaplan fibers. The LCL was identified and isolated by making incisions anteriorly and posteriorly to the ligament and passing an artery forceps deep to the ligament from distal to proximal (Figure 1A). The artery forceps was then used to retrieve the free end of the strip of ITB and pass it deep to the LCL from proximal to distal (Figure 1B).

A bony trough 8 mm wide and 2 to 3 mm deep was created at the attachment site on the Gerdy tubercle before the insertion of the soft tissue anchor (Figure 2, A-C). This made the suture knots less prominent, particularly in thin patients. The free end of the strip of ITB was then reattached anatomically to the Gerdy tubercle using a 5-mm TwinFix titanium anchor with double-loaded Ultrabraid sutures (Smith & Nephew Endoscopy) (Figure 2D). Before the sutures were passed through the strip of ITB and tied in a mattress fashion, the integrity of the fixation of the device within the bone was checked by applying force to the attached sutures.

The reattachment of the ITB to the Gerdy tubercle was augmented with 3 mattress sutures (2 posterior and 1 anterior) using a No. 1 Vicryl suture (Ethicon) (Figure 3A). The defect in the ITB was not formally closed (Figure 3B), but in patients with very lax tissues, such that the posterior edge of the ITB defect was noted to "sag" posteriorly, the margins of the defect were apposed at the midpoint with a single No. 1 Vicryl suture.

Postoperative Rehabilitation

The same postoperative rehabilitation protocol was provided to all patients, although individuals undertook their rehabilitation under the supervision of their physiotherapist of choice. Weightbearing as tolerated was encouraged from the outset, and no braces or splints were used unless a meniscal repair had been performed. Emphasis was placed on early restoration of active knee extension and quadriceps activation. Progression through the rehabilitation program was guided by the presence of pain and swelling. Participants progressed to riding a stationary bike as soon as they were comfortable (usually between 3 and 4 weeks) and commenced gymnasium exercises from 5 to 6 weeks onward. Running was permitted once there was no knee effusion and quadriceps strength was satisfactory (usually from 12 to 16 weeks). Progression to sport-specific drills commenced from 4 months onward, with a graduated return to team training starting around 6 months postoperatively, provided there was no effusion, an essentially full range of motion, good quadriceps strength, good control of a single-leg squat (as assessed by the treating surgeon in the clinic), and unrestricted running and landing. Return to competition sport was permitted after at least 1 month of unrestricted, full-contact training (usually between 9 and 12 months from surgery). Formal return-to-sport testing was not performed on a routine basis.

Follow-up

Patients were reviewed at 12 months postoperatively, at which time they completed a questionnaire that included the IKDC subjective knee evaluation form (International Knee Documentation Committee),[12] KOOS Quality of Life subscale (Knee injury and Osteoarthritis Outcome Score),[26] ACL–Return to Sport After Injury Scale,[33] Marx Activity Rating Scale,[19] and SANE score (Single Assessment Numeric Evaluation) of their current knee function.[35] The questionnaire also included questions about whether they had returned to sport and at what level they had as compared with their preinjury level of participation (same, higher, lower, training only, or not at all) as well as questions about any further injuries (including mechanism details) or surgeries to the knee. The 12-month review also included the following clinical measurements: knee range of motion, side-to-side difference in anterior knee laxity as

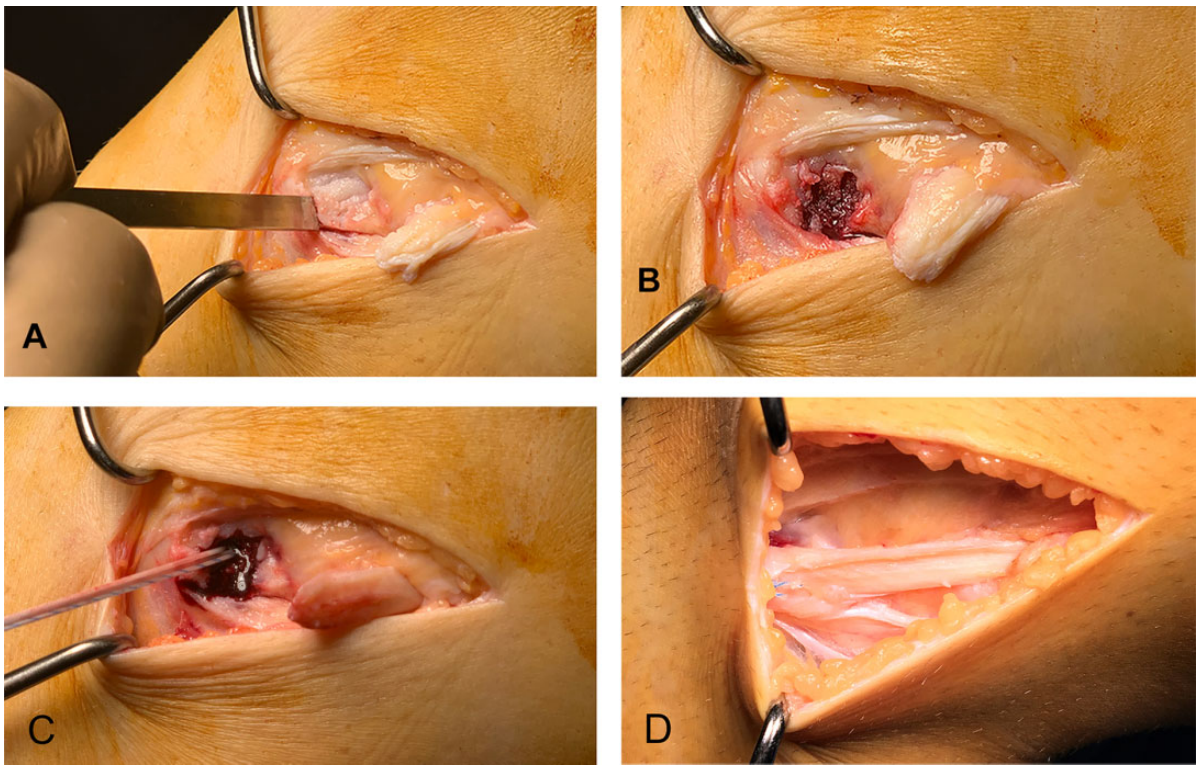


Figure 2. (A) An osteotome is used to create a trough in the Gerdy tubercle. (B) Bony trough in the Gerdy tubercle. (C) Bone anchor is inserted into bony trough. (D) Distal end of strip of iliotibial band is reattached to the Gerdy tubercle.

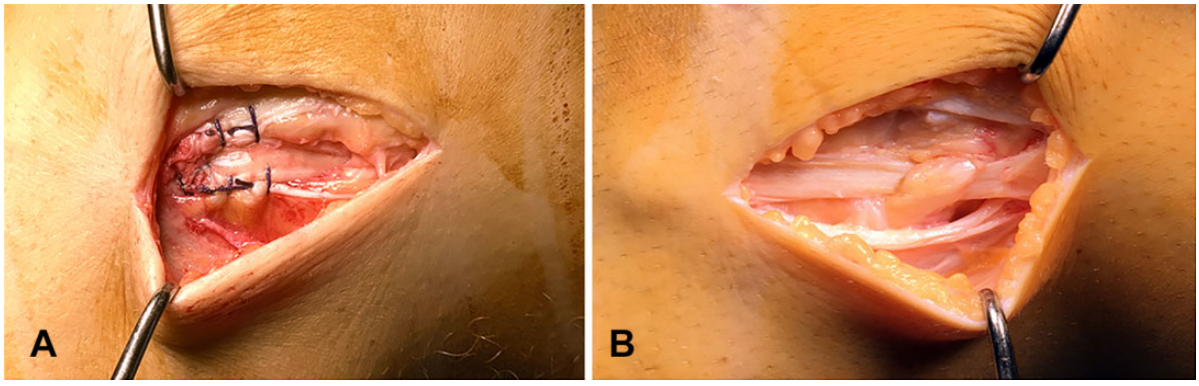


Figure 3. (A) Reinforcement of attachment of strip of ITB to the Gerdy tubercle with interrupted absorbable sutures. (B) ITB defect is usually left open. ITB, iliotibial band.

measured using a KT-1000 arthrometer (Medmetric) at 134 N, and the single hop and triple crossover hop for distance, the last 2 expressed as a limb symmetry index (LSI).

At 24-month follow-up, patients completed a questionnaire covering return to sport and any further injuries or surgery.

Data Analysis

Simple descriptive statistics were used to describe the results, as this was a pilot study only.

RESULTS

There were 21 men and 4 women in the group, with a mean age at surgery of 18.5 years (range, 13.8-28.7 years). Twenty patients (80%) were younger than 20 years at the time of surgery, 4 of whom had open growth plates. The prevalence of the other factors that were used to assess the risk of further ACL injury is shown in Table 1. Although only 2 patients had a grade 3 pivot shift in the consulting room, another 2 had a grade 3 pivot shift under anesthesia.

TABLE 1
Prevalence of Risk Factors in Patient Cohort[a]

Risk Factor	N (%)
Age <20 y at surgery	20 (80)
Family history of ACL injury	11 (44)
Previous contralateral ACL reconstruction	9 (36)
Beighton score ≥4	9 (36)
Grade 3 pivot shift	2 (8)
Plan to return to high-risk sport	25 (100)
Professional or elite level of preinjury sport	17 (68)

[a]ACL, anterior cruciate ligament.

All patients planned to return to a high-risk sport (Australian rules football, 15; soccer, 5; basketball, 2; netball, 1; rugby, 1; freestyle skiing, 1). All but 1 patient had ≥3 risk factors, including 1 patient with 7 risk factors, 4 with 5 risk factors, and 8 with 4 risk factors. The other patient had 2 risk factors.

Lachman testing under anesthesia at the time of surgery revealed the following grades: 1+ in 2 patients, 2+ in 19 patients, and 3+ in 4 patients. The pivot-shift grade under anesthesia was as follows: grade 1 in 1 patient, grade 2 in 20 patients, and grade 3 in 4 patients. Medial meniscal tears were present in 4 (16%) patients. Of these tears, none were repaired, 2 were partially resected, and 2 were stable and not addressed surgically. Lateral meniscal tears were present in 9 (36%) patients. Of these tears, 2 were repaired, 3 were partially resected, and 4 were not addressed surgically. Chondral damage (International Cartilage Repair Society grade 2) was present in 2 patients.

There were 3 complications. One patient (hamstring tendon graft) had an arthroscopic washout 9 weeks postoperatively to exclude septic arthritis. No organism was seen or cultured, and the knee settled. One patient (quadriceps tendon graft) had the LET soft tissue anchor and associated sutures removed 10 weeks postoperatively because of recurrent local infection. One patient (hamstring tendon graft) had arthroscopic debridement of a cyclops lesion 10 months postoperatively because of recurrent knee effusions. All 3 patients returned to competition sport at their preinjury levels.

At 12-month follow-up, return-to-sport data were available for 24 of 25 patients: 13 had returned to training; 2 were playing sport at a lower level than preinjury; 7 were playing at the same level or higher than preinjury; and 2 had not returned to sport but were planning to do so. The mean SANE score was 94/100 (range, 80-100); the mean IKDC score, 92/100 (range, 75-100); the mean Marx score, 13/16 (range, 6-16); the mean ACL–Return to Sport score, 85/100 (range, 61-100); and the mean KOOS score, 77/100 (range, 57-100). Side-to-side differences in anterior knee laxity were as follows among 18 patients: 0 mm in 4 patients, >0 to 3 mm in 13 patients, and >3 to 5 mm in 1 patient. A further 4 patients had Lachman testing only: 0 in 3 patients and 1+ in the other. Pivot-shift results were as follows among 22 patients: grade 0 in 20 patients and grade 1 in 2 patients. The mean LSI for the single hop was 97 (range, 79-106), and the mean LSI for the triple hop was 102 (range, 93-111). The mean side-to-side difference was 0.7° (range, –28° to 25°) for standing flexion, 0.2° (range, –10° to 13°) for active flexion, and 2.2° (range, –5° to 15°) for passive flexion. The mean extension deficit was –0.1° (range, –5° to 4°).

At 24-month follow-up, return-to-sport data were available for 23 of 25 patients: 17 (74%) were playing at the same level or higher than preinjury; 2 were playing at a lower level; and 4 were not playing sport. It should be noted that the 2 patients who were playing at a lower level than preinjury were restricted in the level at which they could play because of government-imposed restrictions on sport attributed to the COVID-19 pandemic. Of the 4 not playing sport, 3 had a further ACL injury and had undergone surgery, while 1 patient had elected to not continue playing because of fear of reinjury.

There were 3 (13%) further ACL injuries within 24 months of surgery. One patient (4%) sustained a graft rupture 12 months postoperatively during unrestricted soccer training. He sustained a contact injury to the lateral side of his operated knee while kicking with the other foot. He was 13.8 years old at the time of surgery and had 3 risk factors. There were 2 (9%) contralateral ACL injuries, including 1 ACL graft rupture. These injuries occurred at 11 and 22 months postoperatively. Both patients were males younger than 17 years at the time of surgery and had 2 and 3 risk factors. Another male (<17 years old at the time of surgery and with 4 risk factors) sustained a contralateral ACL graft rupture at 26 months. He had not had an additional LET procedure with his original contralateral surgery. All further injuries combined with individual patient characteristics are shown in Appendix Table A1.

DISCUSSION

Only 1 patient of 25 (4%) sustained a graft rupture in this pilot study of patients who were considered to be at very high risk and therefore had an additional modified Ellison LET procedure, and there was only 1 complication directly attributable to the LET. It is important to recognize that the patients in this pilot study also had a high rate of return to sport at the same level and included a large proportion of elite athletes. Although the cohort is small and the study represents only an initial clinical assessment of the procedure, the graft rupture rate compares well with previously reported rates in high risk groups in the range of 14% to 22%.[14,17,34] Indeed, it is in the same rate as in the LET group in the STABILITY Study.[9] There were 3 patients (13%) who had a contralateral ACL injury, 1 of which was a graft rupture, and this is also broadly consistent with previously reported data.[14,18,34]

An interesting consideration is that the patients in the current cohort could be considered to be at even higher risk than those enrolled in the STABILITY Study, for which the inclusion criteria were age ≤25 years and at least 2 of the following: grade ≥2 pivot shift, desire to return to high-risk/pivoting sports, and generalized ligamentous laxity.[9] In the current patient cohort, all but 1 patient had ≥3 of the designated risk factors. The majority (80%) were younger than

20 years, and this has been shown to be a strong risk factor for further ACL injury.[17,20,32,34] Just less than one-half (44%) had a positive family history, which has been shown to double the risk of a graft rupture.[34] A grade 3 pivot shift (rather than a grade 2) was regarded as a risk factor, and this was based on the examination findings at the time of the initial consultation rather than under anesthesia. Although only 2 patients had a grade 3 pivot shift in the consulting room, a further 2 had a grade 3 pivot shift under anesthesia with all but 1 of the remainder having a grade 2 pivot shift. Fifteen (60%) played and were returning to Australian rules football, a sport that has been shown to have a very high risk of graft rupture (22%), particularly in young players at the professional level.[14] With regard to the type of sports participation, not only were all patients planning to return to high-risk sports but two-thirds were also playing at an elite or professional level at the time of their injury. At the 2-year follow-up, 75% were playing at the same level or higher. The patients who were playing at a lower level at 2 years were restricted to that level by COVID-19–related government-imposed restrictions. Finally, just over one-third (36%) had a prior contralateral ACL reconstruction. Thus, although the size of the cohort is small, it does suggest that the modified Ellison procedure may provide similar benefits, in terms of reducing the risk of graft rupture, as the modified Lemaire procedure.

It is worth noting that the patients in this cohort had either a hamstring tendon or a quadriceps tendon graft. A recent systematic review reported that quadriceps tendon grafts have comparable clinical and functional outcomes, as well as graft survival rates, relative to hamstring tendon and patellar tendon grafts, but less harvest site pain as compared with patellar tendon grafts and better functional outcome scores than hamstring tendon grafts.[21] However, a large meta-analysis showed a slightly reduced overall graft rupture rate with patellar tendon grafts (2.80%) when compared with hamstring tendon grafts (2.84%).[27] Furthermore, the MOON Group (Multicenter Orthopaedic Outcomes Network) reported twice the graft rupture rate with hamstring tendon grafts than with patellar tendon grafts in high school and college athletes.[13] To date, the reported rates of further ACL injuries after a primary ACL reconstruction combined with a LET procedure have been confined to hamstring tendon grafts, although they have been compared with both isolated hamstring and patellar tendon grafts.[2,9,11,31] The role of LET procedures in reducing the graft rupture rate when using patellar tendon or quadriceps tendon grafts is unclear and warrants further investigation.

As mentioned previously, the described modified Ellison procedure has several potential benefits over a modified Lemaire or MacIntosh procedure or an anterolateral ligament reconstruction. Because there is no fixation of the ITB to the femur, it is a forgiving surgical procedure in the sense that the technique is not dependent on the angle of knee flexion, the rotation of the tibia, or the tension applied to the strip of ITB at the time of fixation (it is anatomically reattached to the tibia). This, in turn, reduces the risk of overconstraint of internal tibial rotation, which is supported by biomechanical testing in a cadaveric model.[5]

Devitt et al[5] tested cadaveric knees in a 6-degree-of-freedom robotic system through 0° to 90° of knee flexion. A simulated pivot shift and kinematic testing, both with loading of the ITB, were performed in the intact knee and in an anterolateral capsule–injured knee before and after a modified Ellison procedure.[5] The modified Ellison procedure reduced both isolated and coupled internal rotation as compared with the sectioned state.[5] During isolated testing, internal tibial rotation was reduced to close to that of the intact state except at 30°, when it was slightly overconstrained.[5] During the simulated pivot shift, internal rotation with the modified Ellison was less than that in the intact state at 15° and 30°.[5] Using the same model, Lord et al[16] also reported that a modified Lemaire procedure significantly decreased internal rotation at 30°, 60°, and 90° when compared with the intact state. In a similar laboratory study, Neri et al[22] found that the modified Ellison procedure restored overall internal rotation kinematics to the normal intact state through the full range of knee flexion but was most effective from 0° to 45° of flexion. However, the Lemaire and modified MacIntosh tenodeses overconstrained internal rotation as compared with the intact condition.[22]

If future studies show it to be equivalent in terms of reducing the risk of graft rupture, the simplicity of the modified Ellison procedure is attractive. In addition, it appears suitable for skeletally immature patients in that it does not require a fixation device in the region of the distal femoral physis. When a LET is fixed to bone proximally, it could act as a tether on the lateral side of the distal femoral physis and cause a valgus deformity, as demonstrated in a skeletally immature canine model when a transphyseal ACL reconstruction was excessively tensioned.[6] Being fixed to bone only at the Gerdy tubercle, which is within the tibial epiphysis, a modified Ellison LET does not pose the same risk. Whether the use of a modified Ellison procedure in combination with a soft tissue autograft in skeletally immature can reduce the graft rupture rate to that of patellar tendon grafts in young but skeletally mature patients also warrants investigation.

It is interesting to consider that LET procedures as an augmentation of a primary ACL reconstruction had largely come and gone in the past but are now being used again. During the 1990s, LET procedures largely fell from favor in the setting of primary ACL reconstruction, particularly in North America. This was in part due to concerns about the potential for overconstraint and causing or accelerating the development of osteoarthritis, although this has subsequently been shown not to be the case.[4] But the reason was mainly that LET augmentation did not appear to add any clinical benefit when compared with isolated intra-articular ACL reconstruction.[23,24] Nonetheless, LET procedures continued to be used as an augmentation of ACL reconstruction in other parts of the world, particularly Europe, with satisfactory results being reported at long-term follow-up.[25,36] There is now contemporary evidence of a reduced graft rupture rate,[9,31] albeit confined to hamstring tendon grafts, although not all studies have come to the same conclusion.[2,11] The latter 2 studies were likely to have been underpowered to detect a difference in graft rupture

rate, but they also included older patients. From systematic reviews, it seems clear that the addition of a LET can reduce the pivot shift, although this may be confined to patients with more chronic ACL insufficiency, but it does not appear to affect anterior tibial translation or clinical outcomes such as the IKDC score.[3,10,30] It seems that identification of the subgroup of patients who may benefit from an additional LET, at least from the perspective of a reduced risk of graft rupture, is paramount. This, in turn, depends on a clearer understanding of risk factors for ACL graft rupture. Of the factors considered to put a patient at increased risk of graft rupture and therefore inclusion in the STABILITY Study,[9] only young age and a return to strenuous sports have high-level evidence to indicate that they are indeed risk factors.[17,34] Pivot-shift grade, ligamentous laxity, and significant knee hyperextension are at this stage speculated to be risk factors and therefore need further investigation. Of the other factors used to assess the risk of graft rupture in the current study, family history is supported in the literature[34] but not a prior contralateral ACL injury.

There are limitations to this pilot study. The cohort size is small, and there is no comparative cohort. It should therefore be seen in the context of being a pilot study aimed at determining whether the modified Ellison procedure is safe and broadly comparable to other LET procedures in terms of outcomes. There is a risk of selection bias in that other patients undergoing primary ACL reconstruction during the same period may have had a similar number of the designated risk factors but not had a LET procedure. Nonetheless, the patient cohort was clearly at a high risk of graft rupture, and all patients who had a LET procedure were included. The patients have been followed only to a minimum of 2 years, so longer-term outcomes are not available.

CONCLUSION

The use of the modified Ellison procedure as a LET augmentation of a primary ACL reconstruction to try to reduce the graft rupture rate in a cohort of patients considered to be at a high risk of reinjury appears to be effective and safe with broadly comparable outcomes to other LET procedures. It is a simple procedure with some potential benefits and therefore warrants further investigation.

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APPENDIX

TABLE A1
Patient and ACL Injury Characteristics[a]

Patient	Sport	Professional or Elite Level	Sex	Age at Surgery, y	No. of Risk Factors	Graft Type	Graft Rupture	Contralateral ACL Injury
1	Basketball	—	Male	17.1	3	HS	No	No
2	Australian rules football	—	Female	17.7	5	QT	No	No
3	Australian rules football	—	Male	16.3	4	QT	No	No
4	Soccer	Elite	Male	16.7	3	HS	No	Yes
5	Australian rules football	—	Male	15.7	5	HS	No	No
6	Australian rules football	Professional	Male	20.2	4	QT	No	No
7	Freestyle skiing	Professional	Male	22.9	3	QT	No	No
8	Australian rules football	Professional	Female	19.0	5	HS	No	No
9	Basketball	Professional	Female	28.7	4	HS	No	No
10	Australian rules football	—	Male	15.8	4	HS	No	Yes
11	Australian rules football	Professional	Male	19.8	3	QT	No	No
12	Soccer	Elite	Male	13.8	3	QT	Yes	No
13	Netball	Elite	Female	14.4	4	HS	No	No
14	Australian rules football	—	Male	16.9	2	QT	No	Yes
15	Soccer	Elite	Male	18.0	4	QT	No	No

(continued)

TABLE A1 (continued)

Patient	Sport	Professional or Elite Level	Sex	Age at Surgery, y	No. of Risk Factors	Graft Type	Graft Rupture	Contralateral ACL Injury
16	Rugby	Professional	Male	21.4	4	HS	No	No
17	Australian rules football	Elite	Male	19.3	5	QT	No	No
18	Soccer	Elite	Male	18.1	3	HS	No	No
19	Soccer	Elite	Male	19.6	3	QT	No	No
20	Australian rules football	Elite	Male	19.5	7	QT	No	No
21	Australian rules football	Professional	Male	25.2	4	QT	No	No
22	Australian rules football	—	Male	15.6	3	QT	No	No
23	Australian rules football	Elite	Male	18.3	3	QT	No	No
24	Australian rules football	Elite	Male	18.2	3	HS	No	No
25	Australian rules football	—	Male	14.9	3	HS	No	No

[a]Dashes indicate nonprofessional/nonelite athletes. ACL, anterior cruciate ligament; HS, hamstring tendon graft; QT, quadriceps tendon graft.