The Addition of Either an Anterolateral Ligament Reconstruction or an Iliotibial Band Tenodesis Is Associated With a Lower Failure Rate After Revision Anterior Cruciate Ligament Reconstruction: A Retrospective Comparative Trial

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Purpose: To compare the failure rate in patients who underwent revision anterior cruciate ligament (ACL) reconstruction alone or associated with an extra-articular procedure. Secondary objectives were to compare ACL laxity, patient-reported outcome measures, and complication rates in these patients and, subsequently, to compare the outcomes of patients who underwent revision ACL reconstruction associated with anatomical anterolateral ligament (ALL) reconstruction or lateral extra-articular tenodesis (LET). **Methods:** This was a retrospective comparative study. Patients were classified into 2 groups, according to whether (group 2) or not (group 1) an extra-articular reconstruction was performed. Patients who underwent an extra-articular procedure were further divided into ALL reconstruction (group 2A) and LET (group 2B). Baseline demographic variables, operative data and postoperative data were evaluated. **Results:** The groups with (86 patients) and without (88 patients) an associated extra-articular reconstruction had similar preoperative data. Group 2 had a lower failure rate (4.6% vs 14.7%; $P = .038$), better KT-1000, better pivot−shift, and better Lysholm. There was no difference regarding complications, except more lateral pain in group 2. Regarding the groups who underwent ALL reconstruction (41 patients) and LET (46 patients), group 2A showed better Lysholm scores. Both groups had similar failure rates and complications. **Conclusions:** Patients who underwent revision ACL reconstruction with a laterally based augmentation procedure had a lower failure rate than patients who underwent isolated revision ACL reconstruction. KT-1000 and pivot−shift examination were also significantly better when a lateral augmentation was performed. Complications were similar except for an increase in lateral pain in the augmented group. No clinically important differences were found when comparing the LET group to the ALL group other than a statistical improvement in the Lysholm functional scale, likely not clinically meaningful, favoring the ALL group and an increased duration of post-operative lateral pain in the LET group. **Level of Evidence:** III, retrospective comparative therapeutic trial.

Most patients presenting with an anterior cruciate ligament (ACL) injury benefit from surgical reconstruction. In case of reconstruction failure, the revision surgery is usually more complex and has worse functional outcomes than primary reconstructions.[1-5] In the recent past, patients with a greater risk of ACL

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reconstruction failure, including those who underwent revision reconstruction, were placed in a group of patients who could benefit from the association of an anterolateral extra-articular procedure, either with the anterolateral ligament (ALL) reconstruction or the lateral extra-articular tenodesis (LET).[6,7]

Although several studies compare additional extra-articular reconstruction techniques to ACL reconstruction in patients with a primary injury, only a few of them have focused on revision reconstruction.[8-21] Studying the revision ACL reconstruction is a more complex task due to the difficulty in standardizing techniques and grafts, besides being less frequent than primary injuries. However, for involving a population at risk, the addition of an extra-articular procedure also should be validated in this scenario. Furthermore, there are few comparative studies in the literature on anatomical ALL reconstruction, performed with a free graft attached to the femur and tibia, passing under the iliotibial band (ITB) and above the lateral collateral ligament, and LET, performed with a strip of the ITB maintaining its attachment to Gerdy's tubercle and redirecting it to the femur, posterior and proximal to the lateral epycondile, passing under the lateral collateral ligament, both in primary and revision cases.[19,22] Only biomechanical studies performed this evaluation yet without a definitive answer regarding the superiority of a technique over the other.[23-28] Among others, this gap in the literature motivated this study.

Thus, the primary objective of this study is to compare the failure rate in patients who underwent revision ACL reconstruction alone or associated with an extra-articular procedure. Secondary objectives were to compare ACL laxity, patient-reported outcome measures, and complication rates in these patients and, subsequently, to compare the outcomes of patients who underwent revision ACL reconstruction associated with anatomical ALL reconstruction or LET.

In revision cases, we hypothesized that patients who underwent extra-articular reconstruction associated with intra-articular reconstruction would present less failure rate, better functional results, and improved knee stability than patients who underwent isolated intra-articular reconstruction. We further hypothesize that there would be no difference between cases who underwent ALL reconstruction or LET.

Methods

This is a retrospective cohort study designed to evaluate the functional outcomes of patients who underwent revision ACL reconstruction with or without an associated extra-articular procedure. Patients operated on between January 2012 and June 2019 in a single institution were included. All patients included in our database that started in 2012 were included. This study was approved by the Research Ethics Committee of our institution. This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University of São Paulo (CAAE 45318521.7.0000.0068; June 10, 2021).

Inclusion and Exclusion Criteria

Patients aged from 18 to 60 years who underwent a one-stage single-bundle revision ACL reconstruction using any graft and with at least 24 months' follow-up were included. Patients who underwent a 2-stage revision were not considered for this study. Patients with associated injuries who required additional procedures such as peripheral ligament reconstructions of the medial collateral ligament or posterolateral ligament complex, posterior cruciate ligament reconstruction, osteotomy or cartilage repair procedures, and patients who lost follow-up were excluded. Patients who already had 1 or more revision surgeries and patients with incomplete data were also excluded from the analysis.

Data Evaluation

Study data were drawn from a database that was filled prospectively during regular postoperative follow-up visits. Patients were always evaluated by knee surgeons, knee fellows, and physiotherapists of our institution during regular follow up, the latter 2 being responsible for filling the database. In a regular basis, after an ACL revision, patients return postoperatively with 1 week, 3 weeks, 6 weeks, 3 months, 6 months, 1 year, and yearly after that. During the years the study was performed, a number of different knee fellows and physiotherapists was responsible for filling the database.

The following parameters were evaluated: baseline demographic variables, such as age, sex, Beighton scale,[29] with evaluation of the contralateral limb to exclude any possible effects of trauma in the injured limb, trauma mechanism of the ACL rerupture (direct or indirect), time between the ACL injury and primary reconstruction, time between failure of the primary reconstruction and revision surgery and preoperative physical examination (KT-1000 [MEDmetric, San Diego, CA] and pivot−shift); operative data, such as type of graft used in the primary reconstruction, type of graft used in the revision surgery, type of extra-articular procedure associated with the ACL revision (ALL reconstruction or LET), cartilage status during revision surgery according to the Outerbridge classification,[30] associated meniscal injuries and treatment (repair or meniscectomy), ACL graft diameter and tunnel diameter and position (the tunnel was always drilled in the same size as the graft and position is described detailed in surgical technique description); and postoperative data, such as follow-up time, postoperative physical examination, postoperative patient-reported outcome measures, including the International Knee Documentation Committee (IKDC[31]) and the Lysholm functional scale,[32] presence of a new graft rupture defined by physical examination demonstrating instability (KT-1000 >5 mm or pivot—shift 2/3), and/or magnetic resonance imaging demonstrating objective graft rupture, presence and duration of postoperative lateral pain from the day of surgery, questioned and reported during follow-up, and complications. The last evaluation of each patient was considered for physical examination and functional scales. Preoperative evaluation for IKDC and Lysholm was not collected. Patient-reported outcome measures were collected face-to-face during follow-up. KT-1000 evaluation was performed with an anterior tibial load of 134 N and the value was reported as side-to-side differences. Pivot—shift evaluation was based on the objective IKDC grading (0 — equal, 1 — glide, 2 — clunk, 3 — gross).

Group Allocation

Patients were initially classified into 2 groups, according to whether an extra-articular procedure was performed associated with the revision ACL reconstruction. Group 1 underwent intra-articular ACL reconstruction only, and group 2 underwent an associated extra-articular reconstruction.

After this analysis, the group of patients who underwent an extra-articular reconstruction associated with the ACL reconstruction was divided into 2 groups; group 2A who underwent anatomical ALL reconstruction, and group 2B who underwent LET.

The allocation of the patients in each group was exclusively done by surgeon indication, not only regarding the addition of an extra-articular procedure but also regarding which associated anterolateral reconstruction was chosen. Also, graft option was exclusively indicated by the surgeon who operated the case. So far, there is no consensus on the mandatory indications for an association of an extra-articular procedure in revision ACL reconstruction and that is why each surgeon in our hospital has autonomy to indicate or not an associated procedure. All surgeries were performed by 3 surgeons (C.P.H., V.B.C.P., R.G.G.) with fellowship training in knee surgery and with experience in ACL reconstruction of our University Hospital, and the surgical technique was standardized.

Surgical Techniques

The revision ACL reconstruction was performed in a single-stage procedure. After arthroscopy for treatment of other intra-articular injuries, the femoral tunnel was performed. The femoral tunnel was always performed with the outside-in technique, close to the ACL anteromedial bundle, avoiding previous tunnels and fixation materials in the outer part of the lateral condyle, as showed by Pioger et al.[33] After the femoral tunnel, the tibial tunnel was drilled from the medial tibial plateau using anatomical landmarks as the anterior horn of the lateral meniscus and the tibial spines. The tunnel diameters were always similar to the graft diameter used in each case. Femoral fixation was performed first with interference screws and tibial fixation was performed later with interference screws with the knee close to full extension. The extra-articular reconstruction was only performed and fixed after the ACL fixation was performed.

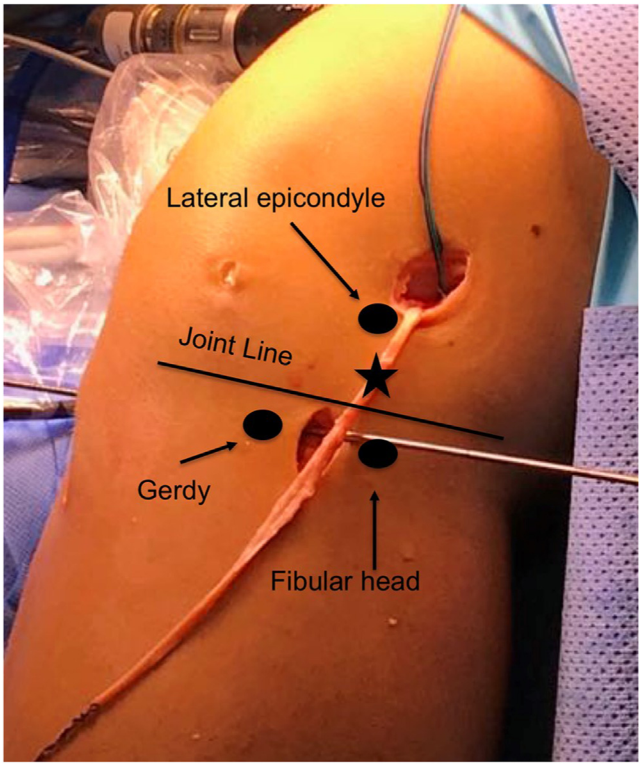

Fig 1. Clinical image of a left knee showing the anterolateral ligament reconstruction. The soft tissue graft (black star) is fixed in a femoral tunnel posterior and proximal to the lateral epicondyle and in a tibial tunnel, between Gerdy's tubercle and the fibular head. All fixations are performed with interference screws.

The ALL reconstruction was performed with a free soft-tissue graft, either autograft or allograft depending on the main graft used for the ACL reconstruction.[34-36] Femoral fixation was performed with an interference screw proximal and posterior to the lateral epicondyle and tibial fixation in a tunnel passing from between Gerdy's tubercle and the fibular head to the anteromedial tibia. The ALL fixation was always performed in full extension and neutral knee rotation. After femoral fixation, the graft used for reconstruction was passed deep to the ITB and superficially to the lateral collateral ligament on its way to the tibia (Fig 1).

For the LET, one variation of the modified Lemaire technique was used.[37] First, a strip of 10 mm wide and approximately 10 cm long from the posterior third of the ITB was dissected, maintaining its insertion in

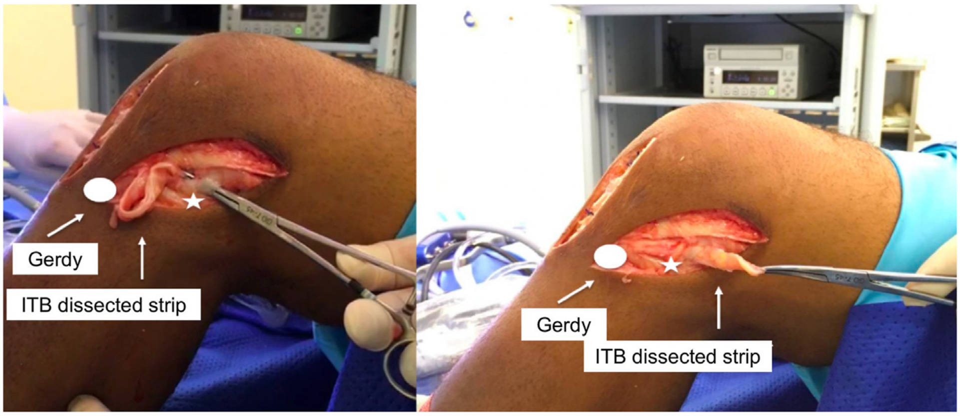

Fig 2. Clinical image of a left knee showing the iliotibial band (ITB) tenodesis. A tape 10 mm wide by 10 cm long is dissected, maintaining its insertion in Gerdy's tubercle and passing below the lateral collateral ligament (white star) before being fixed at a point posterior and proximal to the lateral epicondyle. Femoral fixation is performed with an interference screw or a suture anchor, depending on a possible confluence of previous tunnels in the lateral condyle.

Gerdy's tubercle. This graft was then fixed to the femur in a position posterior and proximal to the lateral epicondyle, in 0° to 30° of flexion, and neutral knee rotation. In its proximal path towards the femur, the graft was passed deeply to the lateral collateral ligament (Fig 2). Fixation was performed with an interference screw or a suture anchor, depending on a possible confluence of previous tunnels in the lateral condyle.

Rehabilitation did not differ between patients. Patients in whom meniscal repair was not performed underwent the same rehabilitation protocol for revision ACL reconstruction in our service. No immobilization or movement restriction device was used. Patients were encouraged to bear weight on the operated limb as tolerated, and range of motion was free and initiated from the first day. Patients undergoing to meniscal repair used a knee extension brace for weight bearing and had the range of motion restricted to 0 to 90° for 4 weeks, with weight-bearing allowed as tolerated and free range of motion after this period. Normally, patients are allowed to return to sports around 12 months after surgery if they have good muscular control, muscular tonus symmetrical to the contralateral side, and no complaints of pain and swelling regarding the operated knee.

Statistical Analysis

Numerical variables were described as mean and standard deviation for normal distribution in the groups or as median and interquartile range when not normally distributed, according to the Shapiro—Wilk test and histogram analysis. The absolute number and percentage described categorical variables within the group. The distributions of variables were analyzed and classified into parametric and nonparametric. Statistical analysis was performed using the Pearson χ^2 test and Fisher test for categorical variables, and the Mann—Whitney *U* test for continuous variables. No initial sample size estimation was performed, as all patients who met the inclusion criteria were analyzed. The post-hoc calculation showed a 61.6% power for failure rate (primary outcome of the study) in the initial evaluation between ACL reconstruction revision associated or not with an extra-articular reconstruction. Statistical significance was considered when the *p*-value was less than 0.05.

Statistical software SPSS 24 (IBM Corp., Armonk, NY) and G * Power 3.1.9.3 (Erdfelder, Faul, & Buchner, Universität Düsseldorf, Düsseldorf, Germany 2009) were used.

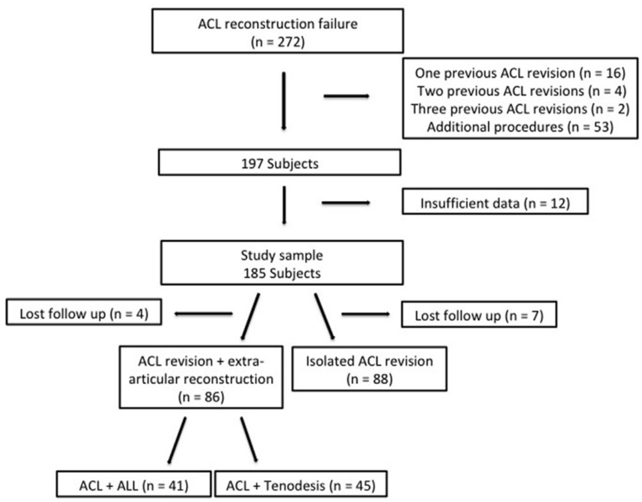

Fig 3. Flowchart of patients included and excluded from the study. (ACL, anterior cruciate ligament; ALL, anterolateral ligament.)

Results

Evaluated Patients

Initially, 272 patients were eligible for the study considering the established inclusion criteria, but 53 were excluded due to additional surgical procedures. Twenty-two patients also were excluded because they already had submitted to an ACL revision reconstruction, 12 patients were excluded because they did not have adequate data for analysis, and 11 patients were lost to follow-up. Thus, a cohort of 174 patients was evaluated (Fig 3). Surgeons 1, 2, and 3 performed 40, 28, and 20 surgeries in Group 1; 24, 10, and 7 surgeries in Group 2A; and 21, 14, and 10 surgeries in Group 2B, respectively. There was no difference in the indicated procedure for the ACL revision between surgeons ($P = .729$)

Groups 1 and 2 Comparison

Comparative demographic data between groups 1 and 2 are described in Table 1. Both groups had similar values for all studied variables. In the postoperative evaluation, the group who underwent an associated extra-articular reconstruction had a lower reconstruction failure rate, a better KT-1000, less quantitative rotational instability in the pivot—shift test, and lower incidence of residual pivot—shift. Group 2 also had a greater postoperative residual lateral pain and when the pain was present, it lasted longer. Despite having a greater incidence of lateral pain in the early postoperative period, patients in group 2 had better values on Lysholm scale. There was no difference in the subjective IKDC scale. Regarding evaluation of the patient acceptable symptom state (PASS) for the IKDC,[38] 27 (30.7%) patients in group 1 and 12 (13.9%) patients in group 2 did not met the cut off value of 75.9 points. This was statistically significant ($P = .008$). Lysholm score PASS has not yet been reported in literature so far (Table 2).

Group 1 had 5 complications, 1 extensive hematoma in the region of the tibial tunnel incision of the revision ACL reconstruction, 1 joint infection that required surgical debridement, 2 cyclops lesions, and 1 superficial infection in the lateral access of the femoral tunnel of the ACL revision. Group 2 had 7 postoperative complications, 1 synovial cyst at the entrance of the tibial tunnel of the ACL revision, 1 superficial infection in the region of the tibial tunnel incision of the ACL revision, 1 joint stiffness that required manipulation, 1 loss of extension of 5°, 1 case of chronic lateral pain in the region of the extra-articular reconstruction, 1 cyclops lesion, and 1 extensive hematoma in the operated leg, but without associated deep-vein thrombosis. There was no difference between groups regarding complications.

Groups 2A and 2B Comparison

Comparative demographic data between groups 2A and 2B who underwent extra-articular reconstruction are described in Table 3. Both groups presented similar values for all studied variables, except for the new ACL injury's trauma mechanism and the type of graft used in the primary reconstruction. There was no difference between the groups regarding the grafts used during the revision ACL reconstruction.

In the postoperative evaluation, groups 2A and 2B also presented similar values for almost all studied variables. Group 2A showed better results than group 2B only for the Lysholm scale. There was no difference in the IKDC scale. Regarding evaluation of PASS for the IKDC,[38] 7 (17.1%) patients in group 2A and 5 (11.1%) in group 2B did not meet the cut off value of 75.9 points. This was not statistically significant ($P = .425$). Both groups also had similar failure rates and complications, including the incidence of lateral pain. However, in the presence of pain, group 2B had longer residual lateral pain than group 2A (Table 4).

Discussion

The main finding of this study is that the addition of an extra-articular reconstruction in revision ACL reconstruction improves knee stability and decreases the reconstruction failure rate. Consequently, we confirm the initial hypothesis of this study. However, both extra-articular reconstruction techniques studied, the ALL reconstruction and the LET, were similar in most of the parameters studied. Therefore, based on the results of this study, it cannot be said that one is superior to the other. Thus, in case of primary ACL reconstruction failure, planning the revision should include the possibility of performing an associated extra-articular reconstruction.

In addition to the improved reconstruction failure rate, the group who underwent an extra-articular reconstruction demonstrated significantly better physical examination measures on KT-1000 and pivot—shift testing. The Lysholm functional scale was also significantly better by mean 5.3 points. However, that margin, while statistically significant, does not reach the threshold for minimum detectable change.[38] The subjective IKDC did not differ between the groups. Even though the minimum detectable change is a metric for "within-individual" change, when it is observed in conjunction with the standard deviation values, it suggests the differences between groups may be clinically insignificant. It should also be questionable if the differences in laxity can be considered clinically meaningful, but even the small differences observed in KT-1000 (mean 0.8 mm) and pivot—shift (15% more patients with positive test), when evaluated together,

Table 1. Demographic Characteristics and Preoperative Evaluation of Patients Included in the Study, Divided into Group 1 (Isolated Revision ACL Reconstruction) and Group 2 (Revision ACL Reconstruction With Associated Extra-Articular Reconstruction)

	Group 1 (Isolated Revision ACL Reconstruction)	Group 2 (Revision ACL Reconstruction With Associated Extra-Articular Reconstruction)	*P*
Number of patients	88	86 (41 ALL and 45 LET)	
Number of surgeries by each surgeon			.729 (NS)
Surgeon 1	40	45 (24 ALL / 21 LET)	
Surgeon 2	28	24 (10 ALL / 14 LET)	
Surgeon 3	20	17 (7 ALL / 10 LET)	
Age, y, mean ± SD (range)	31.0 ± 5.2 (20-48)	29.8 ± 8.3 (18-56)	.103 (NS)
Sex (female)	11 (12.5%)	20 (23.2%)	.063 (NS)
Beighton scale	1.2 ± 1.5	1.6 ± 1.6	.109 (NS)
Trauma mechanism			.347 (NS)
Direct	10 (11.4%)	14 (16.3%)	
Indirect	78 (88.6%)	72 (83.7%)	
Time from injury to primary reconstruction, mo	7.8 ± 6.4	7.7 ± 6.5	.652 (NS)
Time from injury to revision surgery, mo	10.1 ± 7.8	10.5 ± 7.7	.631 (NS)
Type of graft used in primary ACL reconstruction			.261 (NS)
Hamstrings	64 (72.8%)	64 (74.4%)	
Patellar tendon	23 (26.1%)	18 (20.9%)	
Quadriceps	1 (1.1%)	4 (4.7%)	
Type of graft used in revision ACL reconstruction			.153 (NS)
Hamstrings	24 (27.3%)	27 (31.4%)	
Patellar tendon	42 (47.7%)	27 (31.4%)	
Quadriceps	9 (10.2%)	13 (15.1%)	
Tissue bank	13 (14.8%)	19 (22.1%)	
Preoperative KT-1000, mm	7.1 ± 1.0	7.3 ± 1.1	.234 (NS)
Preoperative pivot shift (0-3)			.665 (NS)
1	13 (14.8%)	9 (10.5%)	
2	47 (53.4%)	50 (58.1%)	
3	28 (31.8%)	27 (31.4%)	
Intra-articular graft diameter, mm	9.2 ± 0.9	9.2 ± 0.7	.477 (NS)
Cartilage status (Outerbridge classification)			.780 (NS)
0	18 (20.4%)	20 (23.3%)	
1	35 (39.8%)	40 (46.5%)	
2	24 (27.3%)	18 (20.9%)	
3	8 (9.1%)	6 (7.0%)	
4	3 (3.4%)	2 (2.3%)	
Previous medial meniscectomy			.306 (NS)
No	73 (83.0%)	66 (76.7%)	
Yes	15 (17.0%)	20 (23.3%)	
Previous lateral meniscectomy			.326 (NS)
No	85 (96.6%)	80 (93.0%)	
Yes	3 (3.4%)	6 (7.0%)	
Meniscal injury at the time of revision			.096 (NS)
No	56 (63.6%)	43 (50.0%)	
Yes	32 (36.4%)	43 (50.0%)	
Injured meniscus			.075 (NS)
Medial	16 (50.0%)	27 (62.8%)	
Lateral	9 (28.1%)	14 (32.5%)	
Both	7 (21.9%)	2 (4.7%)	
Meniscal injury treatment			.510 (NS)
Meniscectomy	11 (34.4%)	26 (60.5%)	
Meniscal suture	21 (65.6%)	26 (60.5%)	

NOTE. Trauma mechanism is related to the ACL re-rupture and was divided as direct (contact related) and indirect. Data are presented as mean ± SD.

ACL, anterior cruciate ligament; ALL, anterolateral ligament; LET, lateral extra-articular tenodesis; NS, not significant; SD, standard deviation.

suggest worse clinical results in group 1. The standard deviation for KT-1000 was also higher in group 1, suggesting a greater number of outliers.

Although the complication rate was similar between the groups, the group who underwent extra-articular reconstruction had a greater incidence of lateral pain.

Table 2. Functional Tests, Physical Examination, Graft Rupture Rates, and Complications of Patients Included in the Study, Divided Into Group 1 (Isolated Revision ACL Reconstruction) and Group 2 (Revision ACL Reconstruction With Associated Extra-Articular Reconstruction)

	Group 1 (Isolated Revision ACL Reconstruction)	Group 2 (Revision ACL Reconstruction With Associated Extra-Articular Reconstruction)	*P*
Follow-up time, mo, mean ± SD (range)	35.3 ± 12.9 (r24-84)	32.8 ± 9.1 (24-60)	.378 (NS)
Reconstruction failure/re-rupture	13 (14.7%)	4 (4.6%)	**.038**
Postoperative KT-1000, mm	2.4 ± 1.6	1.6 ± 0.9	**<.001**
Postoperative pivot shift (0 to 3)			**.035**
0	42 (47.8%)	54 (62.8%)	
1	37 (42.0%)	30 (34.9%)	
2	9 (10.2%)	2 (2.3%)	
Residual pivot shift	46 (52.2%)	32 (37.2%)	**.045**
Subjective IKDC	79.1 ± 11.7	83.6 ± 9.4	.896 (NS)
Lysholm	82.6 ± 11.1	87.9 ± 8.7	**<.001**
Postoperative complications	5 (5.7%)	7 (8.1%)	.563 (NS)
Residual lateral pain	14 (15.9%)	62 (72.1%)	**<.001**
Lateral pain time from the surgery day, mo	1.2 ± 0.6	3.2 ± 2.0	**<.001**

NOTE. KT-1000 evaluation was performed with an anterior tibial load of 134 N and the value was reported as side-to-side differences. Pivot—shift evaluation was based on the objective IKDC grading (0 — equal, 1 — glide, 2- clunk, 3 — gross). Data are presented as mean ± SD. *P* values in bold are statistically significant.

ACL, anterior cruciate ligament; IKDC, International Knee Documentation Committee; SD, standard deviation.

It can be considered a negative point of its association with intra-articular ACL reconstruction. The lateral pain in group 2 was greater than 70%, the most common complaint and complication for these patients. In addition, these patients had residual discomfort a mean of two months longer than patients who underwent isolated ACL reconstruction. Based on these data, perhaps for some patients with a high pain level preoperatively who are at relatively low risk of recurrent tear, it might warrant more careful weighing of whether or not to perform a concurrent associated anterolateral procedure.

The use of different types of grafts can be considered a bias in this study. In the initial comparison between the groups with and without associated extra-articular reconstruction, despite the great similarity in the primary reconstruction, in which the hamstrings were predominant, confirming a worldwide trend towards its use,[39,40] in revision cases, there was a predominance of patellar tendon graft, although without a statistical difference, in the isolated ACL reconstruction group. In the comparison between groups 2A and 2B, there was a statistical difference in the graft used for primary reconstruction, with a predominance of hamstrings in the group who underwent LET. However, at the revision time, there was no difference between the groups. We believe that in revision cases, standardization of grafts is not generally feasible since it depends on what type was used in the primary reconstruction and on the availability of allografts.[41,42] Graft choice for revision ACL reconstruction also depends on the size and position of the existing tunnels, since it can be easy to fill a well-placed but widened tunnel with a bone block graft than a pure soft tissue graft. For the femoral tunnel, it is normally easier to avoid previous tunnels using the outside in technique, as was done in this study, and for the tibial tunnel it is also not difficult to change tunnel direction to avoid previous tunnels when only one tunnel was previously performed. As a practical rule in clinical routine, in cases of initial reconstruction with the patellar tendon, hamstrings graft for revision is normally used and vice versa. Quadriceps tendon is also an option when the patient has a relative contraindication for the most-used grafts previously mentioned, but still not used very often in our clinical practice. Currently, at the revision time, in case of hamstrings use, we recommend anatomic ALL reconstruction, and in case of the patellar tendon or quadriceps use, we recommend the modified Lemaire procedure, as no important superiority was demonstrated by one technique over another, and this combination is generally more feasible according to the grafts available.

Studies comparing primary ACL reconstruction to laterally augmented primary reconstructions have generally shown benefits to adding a laterally based augment.[37,43-45] Generally, these studies have included subjects with risk factors for ACL reconstruction failure, such as younger patients, athletes, patients with ligamentous hyperlaxity, chronic ACL injuries, and patients with increased rotational instability using the pivot—shift test.[22,44-47] Although there are no absolute indications for associated extra-articular reconstruction in the literature, the most accepted indications are those reported previously. However, there are not many publications in the revision scenario.[9,13-21,48] Grassi et al.[15] concluded in a systematic review that, even

Table 3. Demographic Characteristics and Preoperative Evaluation of Patients Included in the Study, Divided Into Group 3 (Revision ACL Reconstruction With Associated Extra-Articular ALL Reconstruction) and Group 4 (Revision ACL Reconstruction With Associated LET)

	Group 2A (Revision ACL Reconstruction With Associated Extra-Articular ALL Reconstruction)	Group 2B (Revision ACL Reconstruction With Associated LET)	*P*
Number of patients	41	45	
Age, y, mean ± SD (range)	30.2 ± 8.7 (19-56)	29.5 ± 7.8 (18-46)	.960 (NS)
Sex (female)	8 (19.5%)	12 (26.6%)	.432 (NS)
Beighton scale	1.5 ± 1.7	1.7 ± 1.4	.298 (NS)
Trauma mechanism			**.041**
Direct	3 (7.3%)	11 (24.4%)	
Indirect	38 (92.7%)	34 (75.6%)	
Time from injury to primary reconstruction, mo	7.2 ± 5.9	8.1 ± 7.0	.696 (NS)
Time from injury to revision surgery, mo	8.8 ± 6.6	12.0 ± 8.3	.131 (NS)
Type of graft used in primary ACL reconstruction			**.002**
Hamstrings	24 (58.5%)	40 (88.9%)	
Patellar tendon	15 (36.6%)	3 (6.7%)	
Quadriceps	2 (4.9%)	2 (4.4%)	
Type of graft used in ACL revision reconstruction			.063 (NS)
Hamstrings	17 (41.5%)	10 (22.2%)	
Patellar tendon	8 (19.5%)	19 (42.2%)	
Quadriceps	5 (12.2%)	8 (17.8%)	
Tissue bank	11 (26.8%)	8 (17.8%)	
Preoperative KT-1000, mm	7.6 ± 1.2	7.0 ± 0.9	.061 (NS)
Preoperative pivot shift (0 to 3)			.844 (NS)
1	5 (12.2%)	4 (8.9)	
2	24 (58.5%)	26 (57.8%)	
3	12 (29.3)	15 (33.3%)	
Intra-articular graft diameter, mm	9.0 ± 0.8	9.4 ± 0.6	.081 (NS)
Cartilage status (Outerbridge classification)			.190 (NS)
0	13	7	
1	16	24	
2	10	8	
3	1	5	
4	1	1	
Previous medial meniscectomy			.207 (NS)
No	29 (70.7%)	37 (82.2%)	
Yes	12 (29.3)	8 (17.8%)	
Previous lateral meniscectomy			.098 (NS)
No	36 (87.8%)	44 (97.8%)	
Yes	5 (12.2%)	1 (2.2%)	
Meniscal injury at the time of revision			1 (NS)
No	21 (51.2%)	22 (48.9%)	
Yes	20 (48.8%)	23 (51.1%)	
Injured meniscus			.251 (NS)
Medial	10 (50.0%)	(73.9%)	
Lateral	9 (45.0%)	5 (21.7%)	
Both	1 (5.0%)	1 (4.4%)	
Meniscal injury treatment			.069 (NS)
Meniscectomy	5 (25%)	12 (52.2%)	
Meniscal suture	15 (75%)	11 (47.8%)	

NOTE. Trauma mechanism is related to the ACL re-rupture and was divided as direct (contact related) and indirect. Data are presented as mean ± SD. *P* values in bold are statistically significant.

ACL, anterior cruciate ligament; ALL, anterolateral ligament; LET, lateral extra-articular tenodesis; NS, not significant; SD, standard deviation.

though, in clinical practice, combined anterolateral reconstructions are a common indication associated with ACL revision, there are no high-level studies that support this technique. As a comparison, the failure rate in the systematic review by Grassi et al.[15] was 3.6%, similar to our study (4.6%).

When evaluating the groups who underwent an associated extra-articular reconstruction, the initial differences between groups 2A and 2B, as for the trauma mechanism and the type of graft used in the primary reconstruction, apparently did not affect the final results, even though a significant difference in

Table 4. Functional Tests, Physical Examination, Graft Rupture Rates, and Complications of Patients Included in the Study, Divided Into Group 3 (ACL Revision Reconstruction With Associated Extra-Articular ALL Reconstruction) and Group 4 (Revision ACL Reconstruction With Associated LET)

	Group 2A (Revision ACL Reconstruction With Associated Extra-Articular ALL Reconstruction)	Group 2B (Revision ACL Reconstruction With Associated LET)	*P*
Follow-up time, mo, mean ± SD (range)	34.5 ± 9.7 (24-60)	31.4 ± 8.4 (24-57)	.053 (NS)
Reconstruction failure/re-rupture	3 (7.3%)	1 (2.2%)	.343 (NS)
Postoperative KT-1000, mm	1.8 ± 1.1	1.4 ± 0.7	.161 (NS)
Postoperative pivot shift (0-3)			.735 (NS)
0	24 (58.6%)	30 (66.7%)	
1	16 (39.0%)	14 (31.1%)	
2	1 (2.4%)	1 (2.2%)	
Residual pivot shift	17 (41.4%)	15 (33.3%)	.435 (NS)
Subjective IKDC	84.1 ± 10.9	83.3 ± 7.9	.718 (NS)
Lysholm	89.0 ± 10.2	86.9 ± 6.9	**.047**
Postoperative complications	3 (7.3%)	4 (8.8%)	1 (NS)
Residual lateral pain	33 (80.4%)	29 (64.4%)	.097 (NS)
Lateral pain time from the surgery day (months)	2.2 ± 1.3	4.3 ± 2.1	**<.00001**

NOTE. KT-1000 evaluation was performed with an anterior tibial load of 134N and the value was reported as side-to-side differences. Pivot-shift evaluation was based on the objective IKDC grading (0 − equal, 1 − glide, 2- clunk, 3 − gross). Data are presented as mean ± standard deviation. *P* values in bold are statistically significant.

ACL, anterior cruciate ligament; ALL, anterolateral ligament; IKDC, International Knee Documentation Committee; LET, lateral extra-articular tenodesis; NS, not significant; SD, standard deviation.

a baseline characteristic may have been a confounding factor that neutralized a true difference in outcomes. The parameters of physical examination, associated injuries, type, and diameter of the graft used for the revision surgery did not differ between groups. All postoperative clinical outcomes also were similar between groups 2A and 2B, except for Lysholm scale and postoperative pain. The Lysholm scale showed a statistical difference favoring the ALL reconstruction group; however, as discussed for groups 1 and 2, the 2.1 points difference between groups 2A and 2B tends not to be clinically relevant.[38] Regarding lateral pain, even though the rates were similar, the duration of pain was longer in the LET group. This can be explained by the increased ITB aggression with the modified Lemaire procedure rather than with the ALL reconstruction.

Most studies comparing ALL reconstruction and LET are biomechanical and thus do not account for loosening and accommodation that occurs in vivo with soft-tissue reconstructions[23-26] Inderhaug et al.[27] concluded that a modified Lemaire procedure restored intact knee laxities when fixation was performed at 0°, 30°, or 60° of flexion and the ALL procedure restored normal laxities only when fixation occurred in full extension, and Delaloye et al.[24] concluded that both types of extra-articular reconstruction were similar in terms of restoring knee kinematics, and neither overconstrained the knee. Neri et al.,[28] in turn, concluded that the ALL reconstruction and the modified Elisson-type tenodesis re-establish the normal knee biomechanics, and the Lemaire-type tenodesis overconstrained internal rotation. Geeslin et al.[23] also showed that combination of ACL reconstruction with either ALL reconstruction or the LET procedure resulted in significant reductions in tibiofemoral motion at most knee flexion angles, although overconstraint also was identified.

Regarding clinical outcomes, Hurley et al.[46] performed a systematic review comparing the different existing extra-articular procedures. These authors compared the extra-articular procedures associated with the ACL reconstruction with isolated ACL reconstruction and not the extra-articular procedures with each other. The authors established that ACL reconstructions associated with Cocker-Arnold, Lemaire, or ALL reconstruction result in a lower reconstruction failure rate and improved pivot—shift compared with isolated ACL reconstruction. Ra et al.[22] in a systematic review concluded that the ALL reconstruction compared with LET is better regarding anterior tibial translation, but there is no difference regarding rotational instability and outcomes. Na et al. also performed a systematic review and concluded that the ALL reconstruction seems to be a better option than the LET for improving rotational instability. Rayes et al.[19] directly compared revision ACL reconstruction using patellar tendon associated with LET and hamstrings associated with ALL. Authors concluded both procedures were equivalent and performing and ALL reconstruction in this scenario is safe and effective, similar to what was shown in the current study.

Limitations

The study is possibly underpowered and thus prone to beta error. Subgroup comparison of ALL versus LET groups also likely would benefit from more power. The study's retrospective design, the exclusion of associated injuries that are frequent in ACL revision, and the nonstandardization of grafts in revision cases can be considered important limitations. Also, the indication of an associated extra-articular procedure can also be considered a limitation because it was based on the surgeon's preference and prone to potential selection bias and performance bias. The absence of evaluated parameters such BMI, tibial slope, Tegner scale and preoperative IKDC and Lysholm can also be considered as limitations. Also, there is a potential detection bias related to the clinical assessments across the groups. The absence of radiographic follow up to detect degenerative changes and magnetic resonance imaging follow-up also can be considered as a limitation, as well as the absence of mean long-term follow-up. The fact that many different fellows and physiotherapists filled the database along the years might also be considered a limitation, even though a protocol of evaluation was previously established.

Conclusions

Patients who underwent revision ACL reconstruction with a laterally based augmentation procedure had a lower failure rate than patients who underwent isolated revision ACL reconstruction. KT-1000 and pivot—shift examination were also significantly better when a lateral augmentation was performed. Complications were similar except for an increase in lateral pain in the augmented group. No clinically important differences were found when comparing the LET group to the ALL group other than a statistical improvement in the Lysholm functional scale, likely not clinically meaningful, favoring the ALL group and an increased duration of postoperative lateral pain in the LET group.

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