ORIGINAL PAPER

Clinical, functional, and isokinetic study of a prospective series of anterior cruciate ligament ligamentoplasty with pedicular hamstrings

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Abstract

Purpose Few studies describe the specific results of anterior cruciate ligament reconstruction with pedicled hamstring graft (HG). Our goal was to report the isokinetic, clinical, and functional outcomes over the post–operative year following pedicled hamstring ligamentoplasty.

Methods Twenty-four patients with ACL rupture (mean age 27.4 years) were included prospectively. The technique used a four-stranded HG transplant pedicled to the tibia. The functional result (Lysholm knee score and subjective IKDC score), clinical result (KT-1000, Lachman test, joint amplitudes, objective IKDC score), and isokinetic complication occurrence were analyzed at six months and 12 months follow-up. The functional results, clinical parameters, and complications were analyzed at 30 months follow-up. The comparison of the variables with the various regressions was carried out by a Wilcoxon sign test.

Results Twenty-one patients were reviewed at six, nine, 12, and 30 months. The mean Lysholm knee score was 90/100 at six months, 96/100 at one year, and 95/100 at 30 months. The mean subjective IKDC score was 77/100 and 89/100 at six and 12 months, and 91/100 at 30 months. The mean difference in laxity compared with the healthy knee was 1.4 mm at six months, 1.9 mm at 12 months, and 2 mm at 30 months. The objective IKDC score was A or B for all patients at 12 and 30 months. The average quadriceps strength deficit decreased from 27 to 16% between six and 12 months post–operative ($p = 0.0091$) and the average flexor deficit from 23 to 12% ($p = 0.0084$). No complications were identified.

Conclusion The abovementioned technique allows reaching functional, clinical, and isokinetic results comparable with the standard techniques while preserving the mechanical and biological interest of tibial insertion.

Keywords Isokinetic · Hamstrings · ACL reconstruction · Ligamentoplasty

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Level of evidence: Prospective study, level II.

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Introduction

Anterior cruciate ligament reconstruction surgery (ACLR) is a widely performed surgical procedure. The most important objectives of a well-performed ACLR surgery are restoration of a functional knee for activities of daily living, resuming sports activities to a comparable level, and protection of intimate chondro-meniscal structures. Successful surgery requires a painless, stable knee with complete restoration of joint range of motion and muscle strength.

Various ACL reconstruction grafts have been described in the literature for many years. Hamstring tendons have always been a valid option as an autograft for ACLR. These muscles restrain anterior tibial translation and participate in the stability of the knee [1, 2]; thus, removal of their tibial attachment raises the question of post–operative functional recovery. ACL reconstruction using hamstring autograft with preserved

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tibial insertion is a technical variant [3]. This variant has a theoretical anatomical and biological advantage of preserving the vascularization and innervation of the graft by preserving the anatomical insertion of the tibial tendons [4, 5]. Moreover, we showed in a previously anatomical study that preserving the tibial insertion of hamstring tendons intended for ACLR increases the maximum load to failure at the tibial tunnel, and under these experimental conditions, it seems that adding a tibial screw increases the pull-out strength of the graft by + 25% in absolute terms [6].

To our knowledge, few series report this pedicled technique and results have always been considered satisfactory by their authors comparable with others' techniques [5, 7–9]. None evaluated muscle recovery through isokinetic tests, so this study is the first prospective isokinetic report for a pedicled hamstring technique.

The objective of this work was to prospectively evaluate the isokinetic results at six and 12-month post–operative follow-up, but also clinical and functional results during the year following ACL reconstruction with a pedicled hamstring autograft. Our hypothesis was that the clinical and functional results would be good, despite the existence of a muscle deficit at six and 12 months post–operatively, and clinical and functional results at 30 months would be good too comparable with literature data.

Materials and methods

Study design

This was a prospective mono-centric study conducted from July 2015 to August 2016. Follow-up was done up to 30 months by a non-operator examiner.

The approval of the ethics committee of the University Hospital of Strasbourg has been granted with authorization number "FC/dossier 2016/85." All patients signed an informed consent.

The inclusion criteria were (1) any patient operated on with ACL using the pedicled hamstring transplant, (2) operated on by the same surgeon (ME), (3) with or without associated meniscus lesion, and (4) up to 18 years old.

The exclusion criteria were (1) a history of surgery (ACL reconstruction, osteotomy, prosthesis) of the homolateral knee or of the opposite knee, (2) multi-ligament lesions, (3) contra-indications to isokinetic evaluation, and (4) refusal to participate in this study.

There was no control group.

Evaluation

Patients were examined at inclusion, at six months (M6), at 12 months (M12), and 30 months (M30) post–operatively by a single non-operator examiner (DB). The rehabilitation protocol was unique and return to sports in the axis was allowed at the beginning of the fourth post–operative month and sports with change of direction at the beginning of the seventh post–operative month.

Pre–operative clinical examination data included joint range of motion measurement, Lachman test, and International Knee Documentation Committee (I.K.D.C) objective score [10].

At M6, M12, and M30, an instrumental measurement of the laxity of both knees was performed using a KT1000® arthrometer. The forward translation in maximum manual mode was measured bilaterally and compared. The subjective I.K.D.C [11] and Lysholm [12] functional scores were collected. The type of sport activity and the level of practice (identical, lower, or higher than the pre–operative level) were noted.

An isokinetic evaluation of the flexor and quadriceps torque peak comparing the operated side with the healthy side was performed according to a protocol developed by an isokinetic re-education physician on a CON-TREX Multijoint® machine. The isokinetic evaluation was performed only at M6 and M12. Complications were noted (instability, iterative rupture, infection, algodystrophy).

Series

Twenty-four patients satisfying the inclusion and exclusion criteria were selected for the study. Over the same period, 80 patients had been operated for a serious ligament problem without satisfying the criteria (same operator, ME). Twenty-one patients (21/24) participated in a sport activity prior to the injury. In all cases, it was a pivot sport. (Table 1).

Pre–operative imaging (MRI) assessment revealed that 18 patients had an isolated ACL lesion. In six cases, there was an associated meniscal lesion (5 of the medial and 1 of the lateral meniscus), sutured in two cases and resected in four cases.

Table 1 Characteristics of patients in the initial series

Sex	18 men 6 women	
Side	17 right 7 left	
Age	27.4 years (15.2–45.4)–median 26 years	
Average delay	18.5 months (0.5–120)	
Motion range	Flexion	128° (100–140°)
	Extension	0° (10 to − 5°)
Subjective IKDC	62.8/100 (18.4–87.4/100)	
Objective IKDC	A, 0; B, 0; C, 14; D, 10	
Lysholm	68.7/100 (13–95/100)	
Sports	Occasional, 4; regular, 11; competition, 6	

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Surgical technique

ACLR reconstruction using hamstring graft with preserved tibial insertion has the theoretical (1) anatomical and biological advantage of preserving the vascularization and innervation of the transplant by preserving the anatomical insertion of the tibial tendons [3–5], but also has (2) biomechanical advantage with increasing the maximum load to failure at the tibial tunnel [6].

The intervention was arthroscopically conducted with the patient in a supine position with a tourniquet in situ with a technique previously described [3, 6]. The hamstring graft was harvested using an open periosteal stripper after a direct vertical scar 5–6 cm under the joint space. The tibial insertion of hamstring was therefore preserved, and a fourfold hamstring was prepared, with a graft length of 13.5–14 cm for women and 14.5–15 cm for man. The femoral tunnel was made outside-in with a specific ancillary (Lepine Group, Lyon, France). Bone fixation was ensured by interference screws for the tibia and femur (screw Bioviscon®, Lepine Group, Lyon, France). Under experimental conditions, it seems that adding a tibial screw increases the pull-out strength of the graft by + 25% in absolute terms [6]. The femur was fixed first with a maximal tension.

Statistical analysis

The quantitative variables were analyzed by the Wilcoxon sign test with an alpha risk of 5% (XLSTAT®, Addinsoft, Paris, FR). The significance threshold used was $p < 0.05$. Statistical comparison and monitoring of the evolution of variables at different times was performed on patients whose data were available at M6 and M12.

Results

Series at follow-up

Twenty-one patients had a complete evaluation at M6. Three patients did not present for post–operative consultation. Out of these 21 patients, 19 were examined at M12 and M30 and one was interviewed by telephone, i.e., functional and clinical data available for 19 patients (19/21). Sixteen patients had isokinetic evaluation at M6 and M12. Patients were evaluated at an average of six months (5.5–8 months) for the first control and 12 months (10–13.5 months) for the second control, and 30 months for the third one (28–31.5).

Clinical and functional results

The average flexion was 135° (130–140) and average extension was 0° (5–0) already at six months. Two patients had a

Lachman test with a late firm bony end point at M6 and M12 and M30. The mean difference in laxity was 1.4 ± 1.5 mm (− 1 to 4) at M6. At M12, the mean difference was 1.9 ± 1.3 mm (− 1 to 4). At M30, the mean difference was 2 ± 1.2 mm (− 1 to 4). The difference between M6 and M12 was significant ($p = 0.0261$), but not the difference between M12 and M30 ($p > 0.05$). Two patients had a laxity difference greater than 3 mm at M6, M12, and M30. One patient complained of instability at M6, persistent at M12 and M30.

The mean Lysholm score at M6 was $90/100 \pm 10$ (63–100), $96/100 \pm 6$ (80–100) at M12, and $95/100 \pm 8$ (80–100) at M30. The improvement was significant between the pre–operative score and M6 ($p = 0.0001$), but also between M6 and M12 ($p = 0.0083$), but not between M12 and M30 ($p > 0.05$). The mean subjective IKDC at M6 was $77/100 \pm 11$ (57–94), $90/100 \pm 8$ (67–100) at M12, and $91/100 \pm$ (67–100) at M30. The IKDC score improved significantly between the pre–operative score and M6 ($p = 0.0003$) and also between M6 and M12 ($p < 10-6$). But no significant difference could be observed between M12 and M30.

At M6, 12 patients had resumed sport activities. Among them, five (5/19) had resumed the same pre–operative activity at a lower level. At M12 and M30, 15 patients had a sporting activity. In three cases, practice and level were identical to that of post–operative. In the other cases, practice and level were lower.

No complications were identified during the follow-up period.

At follow-up, the associated lesion "ACL + meniscus" did not influence the clinical results or the possibility back to sport.

Isokinetic result

The median of the mean deficit of the maximum quadriceps torque in concentric mode at 60°/s on the operated side compared with the healthy side was 27% (19; 40) at M6 and 16% (13; 25) at M12 ($p = 0.0091$).

The median of the maximum hamstring torque deficit:

- In concentric mode at 60°/s on the operated side compared with the healthy side was 24% (20; 31) at M6 and 19% (13; 27) at M12 ($p < 0.05$).

- In eccentric mode at 30°/s, the median deficit of the maximum torque of the operated side compared with the healthy side was 23% (18; 35) at M6 and 12% (2; 19) at M12 ($p = 0.0084$).

At follow-up, the associated lesion "ACL + meniscus" did not influence the isokinetic results.

Discussion

The main objective of this study was to report isokinetic results in the year following surgery, which is to our knowledge

the first prospective isokinetic report for a pedicled hamstring technique, but also to report clinical and functional results at one year. The muscular deficit, evidenced in the sixth post–operative month, persisted in the twelfth month on both muscle groups, although this deficit was lessened over time. Despite these observations, the results showed very good functional recovery in terms of clinical scores and joint range of motion which is comparable with the data in the literature. The working hypothesis was confirmed.

This study had limitations. The small number of subjects included is related to restrictive inclusion and exclusion criteria and the difficulty of obtaining agreement to participate in this young and migrating population. However, to our knowledge, this is the first work evaluating pedicled hamstring ACL reconstruction in an isokinetic, comprehensive, prospective, and continuous study. Indeed, the literature is relatively poor on the specific subject of pedicled hamstring being mainly used for the realization of a mixed intra- and extra-articular ligamentoplasty [8, 9, 13], and there is no data about isokinetic evaluation. Only Ruffili et al. [5] and Buda et al. [7] reported the clinical results of an intra-articular ligamentoplasty similar to ours. The comparison with the literature thus remains difficult.

Clinically, the results obtained are comparable with the data in the literature. The recovery of a mobile, dry, and painless knee was consistently observed at M30. Despite a significant difference in laxity between M6 and M12, there is a difference in mean laxity at M12 but which remains under 2 mm, with only one case of clinical instability. There is no difference between M12 and M30. These data are comparable with those published, especially for the comparison between hamstring graft (HG) and bone-patellar ligament-bone [14] at 1-year follow-up. In a more long-term study, Gifstad et al. [15] reported an average difference in objective laxity of 1.4 mm at seven years of age with a semi-tendinous and slender transplant doubled without pedicle, and identical with a patellar-bone ligament-bone transplant. Finally, for Barenius et al. [16], with a 4-strand semi-tendinous transplant, this difference in objective laxity was 2 mm at ten years. Several reasons could explain the evolution of the measured laxity. First of all, it is necessary to specify that the knee laxity devices used in regular practice are not comparable with one another; thus, caution must be taken when comparing results from studies using these different devices [17]. This could be the sliding of the transplant along the interference screws in the first months after surgery. For Murakami et al. [18], bone integration of the tendon graft is obtained between seven and 12 months post-operatively and for Figueroa et al. [19], it is obtained at M6 for 90% of cases. For Cuti et al. [20], muscle tissue is a better source of stem cells than tendon tissue, indeed capacity of muscle tissue for enhancement integration and ligamentization of ACLR hamstring was shown, so muscle tissue should not be treated as waste. Another hypothesis could be a loosening

of the tendon transplant; all the more so as the pre-tension imposed is limited given the pedicled nature of the transplant. In order to decrease the risk of secondary instability, it is important to conserve the ACL remnant especially when this remnant is connecting the femur to the tibia because mechanoreceptors persist for a long time in this kind of remnant [21]. However, no correlation between functional scores (Lysholm, IKDC) and laximetry was found. In a comparable study, with preservation of tibial insertion of HG, Ruffili et al. [5] found an IKDC score strictly similar to ours. In two comparative studies evaluating HG transplant without tibial insertion conservation versus bone-patellar ligament-bone [14, 15], authors also found scores comparable with ours at one year post–operative, without difference between the compared groups.

In our work for only three cases (3/19), the level of practice remained identical. A 45% rate of return to sport at the same level was found in a longer term by Holm et al. [19, 22] and 55% found by Pinczewski et al. [23] at ten years. For Ardern et al., one-third of patients returned to the same sport at the same level one year after surgery [24]. This difference can be explained by the different perspective of these studies and by the fact that patients were only allowed to resume a pivotal contact sport after six months with a return to competition in the eighth–ninth postoperative months. Although there is no consensus on when to allow return to sports [25, 26], this attitude is classic and adopted by many surgeons.

Even if these clinical and functional results are comparable with the literature, the pedicled hamstring technique is really interesting because preserving the tibial insertion of hamstring tendons increases the maximum load to failure at the tibial tunnel [6]. Indeed, we know that tibial fixation is the weak point of ACLR. Moreover, it seems that adding a tibial screw increases the pull-out strength of the pedicled graft by + 25% in absolute terms [6].

The main isokinetic results observed showed that there was a significant peak torque deficit in the quadriceps and HGs at M6 but which decreased significantly at M12 ($p = 0.0084$ and 0.0091 respectively for the quadriceps and HGs). These results indicate muscle recovery between M6 and M12. These deficits in terms of maximum strength were expected. They are reported by other studies and would persist even beyond 20 years, regardless of the transplant used [14, 27–29].

Comparison with the literature is made difficult by the multiplicity and non-standardization of isokinetic evaluation protocols (angular velocities, number of repetitions, post–operative delays, variable machines). Thus, for Coombs et al. [30], the strength deficit was 21% at M6 and 16% at M12 for the HG, for Kim et al. [31], it was 14% for the HG at 60°/s. For Lee et al. [32], it was 34% for the quadriceps and 21% for the HG to M6 and increased to 22% for the quadriceps and 20% for the HG to M12. Finally, for Yosmaoglu et al. [33], it was 21% for the HG and 18% for the quadriceps at M12. Kramer et al. [34] reported a HG deficit of 4% at two

years of surgery, i.e., a subtotal recovery despite the removal of the two HG tendons. These published values after ACL reconstruction using semitendinosus and gracilis as transplant are quite comparable with our results.

Correlations between these muscle values and functional results (IKDC and Lysholm) were sought. Clinical scores were correlated with quadriceps strength and HG strength at M6. At M12, the correlation persisted only between IKDC score and quadriceps strength on the operated side. Thus, a higher score was associated with a higher force. Condouret et al. [35] found a relationship 2 years after surgery between the IKDC score and quadriceps and HG muscle deficit. Bodkin et al. [36] showed a correlation between functional scores (KOOS and IKDC) and isokinetic results after ACL reconstruction. Pua et al. [37] showed a correlation between Lysholm score and quadriceps and HG strength deficit in the first six months. The results of our study confirm these elements, showing that muscle strength recovery and deficit normalization are associated with an improvement in functional outcome.

Conclusion

The muscle deficit, evidenced in the sixth post–operative month, persists in the twelfth postoperative month on both muscle groups, but an improvement in this deficit is observed over a period of time. Despite this point, the functional and clinical results are comparable with the data in the literature for other ACL reconstruction reference techniques with respect to functional outcomes, thus confirming the working hypothesis.

Compliance with ethical standards

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