

## Clinical Outcome after Anterior Cruciate Ligament Reconstruction Using Hamstring Tendon Autograft: A Prospective Study with 6 Months Follow-up

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Received date: August 23, 2018; Accepted date: September 27, 2018; Published date: October 08, 2018

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### Abstract

**Objective:** The goal of our study is to show that after single-bundle anatomic ACL reconstruction technique using hamstring tendon autograft (quadrupled semitendinosus and gracilis tendons), there is excellent objective knee stability and the return of flexor muscles strength.

**Methods:** 65 patients aged 13–46 entered our study and were operated with a single bundle ACL reconstruction technique using hamstring tendon autograft. The operation and postoperative protocol were standardized. Patients were evaluated at 3 and 6 months postoperatively with clinical examination, KT–1000 measurements, functional scores (Balance index, Hop index, IKDC, isokinetic testing) and subjective questionnaire (Lysholm score, Tegner score).

**Results:** 65 patients were evaluated 3 and 6 months postoperatively. Lachman test was negative in 92% and the pivot-shift test was negative in 89% of patients at 6 months follow-up. KT–1000 stability testing revealed a difference of 1.05 mm ± 2.83. At final follow-up, overall IKDC evaluation grade A and B were obtained in 96% of patients. The mean Lysholm score, 6 months postoperative was 94. There was no statistically significant difference in the angle of peak torque inflexion at 60°/s at 6 months follow-up.

**Conclusion:** Our study shows that the strength of knee flexion six months after harvesting both hamstring tendons returns. However, there is still a statistically significant difference in knee flexion peak torque, when comparing the operative and non-operative side. Single bundle anatomic ACL reconstruction gives excellent knee stability and good clinical results with normal knee range of motion and returns to the appropriate level of activity.

**Keywords:** ACL; Reconstruction; Single bundle; Hamstring tendon; Autograft

### Introduction

Anterior cruciate ligament (ACL) injury is a common injury of the knee joint in professional and recreational athletes engaging in high demanding sports. Studies show, that an ACL deficient knee is unstable and continuation of sports activities can lead to further damaging of the knee joint, resulting in meniscus tears, chondral damage and finally, leading to early joint degeneration [1,2].

ACL functions as a primary restraint to anterior tibial translation, providing 87% of the total restraining force at 30° of knee flexion and 85% at 90° of flexion. Its deficiency leads to anterior subluxation of the lateral and medial tibiofemoral compartments, which is described by Noyes [3]. The primary surgical goal of stable knee and satisfied patient who can return to their pre-injury level of activity, can be achieved by using different graft materials (autograft, patellar tendon, hamstring tendon, quadriceps tendon or allograft), using different surgical techniques (single-bundle, double-bundle) and complying with different postoperative rehabilitation strategies. There are several studies describing postoperative results comparing patellar tendon and

hamstring tendon autografts that found no statistical significant differences between two groups in functional outcome [4-7].

On the other hand, the study of 12,643 patients from the Norwegian Cruciate Ligament registry from 2004-2012 concluded that in the patients with hamstring grafts, there is twice higher risk of revision compared to patients with patellar tendon grafts [8]. Several studies showed superiority of double-bundle (DB) technique regarding postoperative stability [9], better outcomes in rotational laxity (pivot-shift test, KT-1000 grading and IKDC grading) [10] and in terms of restoration of knee kinematics, [11] although there are also studies showing that no significant difference can be found between single-bundle (SB) and double-bundle (DB) technique regarding anterior laxity, stability, proprioception or knee scores [12,13].

Also, by harvesting both hamstrings, the semitendinosus and gracilis tendons, the flexor strength of the knee and internal tibial rotation strength may be lower [14]. The aim of our study is to show that after single-bundle ACL reconstruction technique using both hamstring tendons and complying with appropriate rehabilitation protocol, the strength of knee flexion at 6 months follow-up returns and there is also excellent knee stability achieved, despite both hamstring tendons were harvested.

## Methods

Between June 2015 and June 2016, 65 consecutive patients (44 males and 21 females) aged from thirteen to forty-six years, who had clinical instability and MRI positive study for ACL rupture, were enrolled in our study. All patients had either an isolated ACL ligament injury (27 cases) or combination of ACL injury with medial or/and lateral meniscal tear (38 cases). No patient had a history of previous knee surgery. There were forty-four male patients aged from 17-46 and twenty one female patients aged from 13-40 years. The mean age of all patients was  $28.5 \pm 8.05$  years (13-46 years). The mean height and weight was  $176.2 \text{ cm} \pm 8.4$  and  $78.0 \text{ kg} \pm 14.04$  respectively, with average BMI  $24.97 \pm 3.42$ . The average time from injury to surgery was  $16.4 \pm 17.39$  months (1-86 months). The surgeries were performed by senior author and the rehabilitation protocol was standardized for all patients, and performed by experienced physiotherapist. At 3 and 6 months follow-up, patients were examined by the second author. The research was approved by the Slovenian National Medical Ethics Committee.

## Surgical technique

In all patients, the graft was harvested at the pes anserine insertion using minimal oblique skin incision. The underlying Sartorius fascia was longitudinally split and both, the gracilis and semitendinosus tendons were harvested through their entire length using a tendon stripper. After the tendons were cleaned of muscle tissue, a quadrupled graft was made, measuring diameter at least 8 mm. The ends were sutured with bio absorbable Vycril no. 2 sized suture. The graft diameter was determined with caliper and manually pre-tensioned. The reconstruction required two portals. Standard anterolateral parapatellar portal was first made and under optical view. Low far medial parapatellar tunnel was made to ensure the proper femoral tunnel placement.

The femoral tunnel was drilled at the most medial anatomic footprint of the posterolateral bundle, and the diameter of the reamer corresponded to the graft diameter. The tibial tunnel was drilled through central part of the anatomic footprint. Tunnel size was also matched with the graft diameter. Then, the graft was pulled through the tibial tunnel into the femoral tunnel. Femoral fixation was achieved with left or right round-headed threads interference screws (RCI, ART-MAM, Slovenia), depending on the side. The tibial part of the graft was fixated with resorptive interference screw (Linvatec) of appropriate size. The technique is already described in more detail elsewhere [15].

## Rehabilitation

In all patients, the rehabilitation protocol was standardized with accelerated protocol which immediately allowed full weight bearing and gaining full range of motion (Appendix 1). Patients were discharged from hospital only after they achieved full extension ( $0^\circ$ ) and flexion of the knee ( $90^\circ$ ). There was no joint edema and were educated in full weight bearing. The harvested tendons were treated as there was a muscle injury, so our rehabilitation protocol at early phase was concentrated in prevention of further hamstring muscle belly contraction, promoting healing and preventing further injury. Early in the rehabilitation protocol, we added stretching exercises of hamstring muscles and program for strengthening knee flexion with progression in force. Detailed rehabilitation protocol after the hospital discharge is described in Appendix 1 (Supplementary file).

## Follow up evaluation

For evaluation, follow up measurements were performed in 60 patients, 3 months postoperatively and in 65 patients 6 months postoperatively at the rehabilitation center. The patients filled-out Lysholm, Tegner and IKDC questionnaire. Patients were also tested for Lachman and pivot-shift tests, and all were measured for knee range of motion at 3 and 6 months postoperatively. Objective knee stability was tested with KT-1000 at 6 months follow -up. Isokinetic testing at 3 months was performed at  $180^\circ/\text{s}$ , and at 6 months  $60^\circ/\text{s}$  and  $240^\circ/\text{s}$  (BIODEX 4 PRO).

Balance testing was performed at 3 and 6 months (BALANCE SYSTEM SD), while single hop test was performed at 6 months. All objective tests were compared to uninjured side. In 39 patients (60%), the dominant leg was injured. Most of the patients (85%) were injured during sports activities, while others during working (4.5%) or accident (10.5%). Among sports injuries, soccer injuries prevailed (37%).

Statistical analysis was reported as mean  $\pm$  standard deviation. We reported statistical significance as p value less than 0.05. Statistical analysis was performed with SPSS 10.1.

## Results

The mean Lysholm score preoperative was  $71.5 \pm 15.89$  and at the 3 and 6 months  $89.2 \pm 6.56$  and  $93.8 \pm 4.85$  respectively. Overall, six months after surgery, for 32 patients (49%) result was excellent, while in 63 patients (96%) result was good to excellent. Only in 3 patients the result was fair (4%). 29 patients (45%) returned to their pre-injury level of activity, whereas 36 patients had to return to lower level of activity (55%).

As of the activity level of patients pre-injury and evaluated with Tegner score, most of the patients were engaging in level 7 competitive or recreational sports and level 6 recreational sports (32 and 14 respectively). Athletes engaged in level 10 and 9 competitive sports, were four and six respectively. Postoperatively four patients from preoperative level 9 and 10 remained at the same level of activity while others stopped with competitive sports but still remained in recreational sports (level 7 and 6).

Range of motion at 3 and 6 months was  $-0.03^\circ \pm 0.29$  and  $0.15^\circ \pm 1.24$  in extension and in flexion  $132.33^\circ \pm 3.74$  and  $134.77^\circ \pm 2.41$ . Balance index after 3 months for operated and healthy leg was  $2.25 \pm 1.3$  and  $2.41 \pm 1.1$  respectively, with difference  $1.1 \pm 0.42$  ( $p=0.45$ ) and at 6 months showed  $5.53 \pm 2.59$  and  $5.51 \pm 2.89$  with difference of  $1.03 \pm 0.38$  ( $p=0.92$ ).

Single leg hop test six months after surgery of operated leg compared to healthy leg revealed  $147.02 \text{ cm} \pm 28.83$  and in operated  $127.19 \text{ cm} \pm 35.56$  with an average hop index  $0.85 \pm 0.13$  (uninjured/operated leg). In twenty-nine patients hop index was higher than 0.9, in twenty-four between 0.7-0.8, in eleven between 0.5-0.7 and in one patient below 0.5, KT-1000 laxity measurements 6 months after surgery revealed postoperative measurements of  $9.65 \text{ mm} \pm 3.2$  on operated leg and  $8.60 \text{ mm} \pm 3.02$  on uninjured leg with operated to non-operated leg difference of  $1.05 \text{ mm} \pm 2.83$ . Knee stability testing at 3 months revealed 2 patients (3%) with Lachman test 1+ and pivot-shift test 1+.

At six-months there were 5 patients with Lach-man test 1+ and pivot-shift test 1+ (8%) and one patient (2%) with pivot shift-test 2+. Results are shown in Table 1.

		3 months after surgery Patients/ %	6 months after surgery Patients/ %
<b>Lachman</b>	Grade 0	58 (97%)	60 (92%)
	Grade 1	2 (3%)	5 (8%)
	Grade 2	0	0
	Grade 3	0	0
<b>Pivot-shift</b>	Grade 0	58 (97%)	58 (89%)
	Grade 1	2 (3%)	6 (9%)
	Grade 2	0	1 (2%)
	Grade 3	0	0

**Table 1:** Lachman and pivot-shift testing.

Results of isokinetic testing at 3 months are shown in Table 2 and were compared to uninjured leg tested at 180°/s. The testing showed

deficit in extension strength of  $19.7\% \pm 13.25$  ( $p \leq 0.01$ ) and  $14.5\% \pm 11.33$  ( $p < 0.01$ ) in flexion strength. Peak torque/BW deficit in extension and flexion were  $19.7\% \pm 13.25$  ( $p < 0.01$ ) and  $14.5\% \pm 11.33$  ( $p < 0.01$ ) respectively.

	Operated	Healthy	p	Deficit (%)
<b>Peak Torque extension (Nm)</b>	113.96 $\pm$ 33.82	141.86 $\pm$ 34.91	<0.01	19.78 $\pm$ 13.25
<b>Peak Torque/BW extension (Nm)</b>	146.38 $\pm$ 32.38	182.80 $\pm$ 30.24	<0.01	19.78 $\pm$ 13.25
<b>Peak Torque flexion (Nm)</b>	72.18 $\pm$ 17.85	85.21 $\pm$ 21.08	<0.01	14.55 $\pm$ 11.33
<b>Peak Torque /BW flexion (Nm)</b>	93.05 $\pm$ 15.34	109.65 $\pm$ 17.40	<0.01	14.53 $\pm$ 11.33
<b>Agonist/antagonist (%)</b>	66.16 $\pm$ 16.24	60.73 $\pm$ 9.27	0.02	

**Table 2:** Isokinetic testing at 180°/s at 3 months.

Isokinetic testing at 6 months showed deficit in extensor strength at 60°/s and at 240°/s of  $15.8\% \pm 14.77$  and  $13.4\% \pm 11.39$  respectively, while in flexor strength the deficit was  $12.2\% \pm 12.64$  and  $7.8\% \pm 12.72$ .

	Operated	Healthy	p	Deficit (%)
<b>Peak torque extension 60°/s (Nm)</b>	178.18 $\pm$ 51.05	212.05 $\pm$ 48.60	<0.01	15.88 $\pm$ 14.77
<b>Peak torque/BW extension 60°/s (Nm)</b>	228.63 $\pm$ 52.25	271.86 $\pm$ 38.24	<0.01	15.89 $\pm$ 14.77
<b>Peak torque flexion 60°/s (Nm)</b>	96.92 $\pm$ 26.47	112.17 $\pm$ 33.08	<0.01	12.28 $\pm$ 12.64
<b>Peak torque/BW flexion 60°/s (Nm)</b>	123.83 $\pm$ 23.41	142.91 $\pm$ 29.11	<0.01	12.27 $\pm$ 12.65
<b>Agonist / antagonist 60°/s (%)</b>	55.64 $\pm$ 10.39	52.83 $\pm$ 9.84	0.07	
<b>Agonist/antagonist 240°/s (%)</b>	69.49 $\pm$ 12.90	65.14 $\pm$ 11.66	0.01	
<b>Peak torque extension 240/s (Nm)</b>	106.91 $\pm$ 31.39	123.12 $\pm$ 31.72	<0.01	13.41 $\pm$ 11.39
<b>Peak torque/BW extension 240°/s (Nm)</b>	136.51 $\pm$ 29.51	157.51 $\pm$ 26.05	<0.01	13.42 $\pm$ 11.39
<b>Peak torque flexion 240/s (Nm)</b>	71.97 $\pm$ 18.05	78.94 $\pm$ 19.78	<0.01	7.84 $\pm$ 12.72
<b>Peak torque/BW flexion 240°/s (Nm)</b>	92.71 $\pm$ 17.67	101.22 $\pm$ 17.14	<0.01	7.82 $\pm$ 12.74

**Table 3:** Isokinetic testing at 60°/s and 240°/ at 6 months.

Measurements of angle of peak torque at 60°/s with comparison to healthy leg at 6 months after surgery showed difference  $-2.6^\circ \pm 9.37$  ( $p=0.03$ ) and  $2.1^\circ \pm 14.41$  ( $p=0.24$ ) in extension and flexion respectively.

	Operated	Healthy	p
<b>Angle of peak torque extension (°)</b>	68.89 $\pm$ 7.69	71.51 $\pm$ 9.66	0.03
<b>Angle of peak torque flexion (°)</b>	40.63 $\pm$ 11.46	38.49 $\pm$ 11.33	0.24

**Table 4:** Angle of peak torque at 60°/s at 6 months.

At 6 months follow-up, the IKDC score showed 35 patients in group A (54%), 27 in group B (42%) and 3 in group C (4%), while no patients were in group D. During the rehabilitation two patients (3%) suffered knee injury with unstable knee and later on revision ACL surgery was performed.

## Discussion

In our prospective study with 6 months follow up, the results showed that also the single bundle (SB) ACL reconstruction using quadrupled hamstring tendons (semitendinosus and gracilis) can give excellent results regarding objective knee stability, improvement in knee function and returning or maintaining level of activity. Our isokinetic testing was focused on evaluating angle of peak torque at 60°/s, strength deficits and H/Q ratio, since we believe that these

parameters should give surgeon understanding of proper post-operative rehabilitation and timing on when to return to activities.

There are studies showing, that double bundle (DB) ACL reconstruction technique can achieve better rotational stability when tested by pivot shift test [16], and by regarding knee function stability [17]. Also, the recent review of nine meta analyses suggested that double bundle (DB) ACL reconstruction technique provides better postoperative knee stability [9]. The study from Ha et al. on contrary showed no significant differences of clinical and functional outcomes between single bundle (SB) and double bundle (DB) ACL reconstruction at 2 years follow-up [18]. Similar results were found also by study of Torkaman A et al. [19]. There is a trend toward anatomic ACL reconstruction regardless of it is a DB or SB reconstruction technique.

Shia et al. found in their study after double bundle (DB) ACL reconstruction negative Lachman test in 44.5% and negative pivot shift test in 85% of patients after an average follow up of 23 months. They concluded that their results are superior regarding the stability testing than compared to single bundle technique [20]. Our clinical examination, on contrary, show negative Lachman test in 92% of the patients and negative pivot-shift test in 89% of the patients after anatomic single bundle (SB) ACL reconstruction technique 6 months postoperatively.

Our previous studies showed good subjective outcomes and objective stability at 5 years follow up with no significant differences in the rate of graft failure when compared between patellar tendon (PT) and ham-string tendon [7]. Similar results regarding the graft type were found in the study by de Padua et al. [21]. In present study there was a re-rupture of ACL ligament in two patients (3%) and re-reconstruction of the ACL in these two patients was performed.

Isokinetic testing is frequently used method to objectively assess thigh muscular strength after ACL reconstruction and to diagnose thigh muscle imbalance during rehabilitation protocols. It gives surgeon objective measurements of rehabilitation protocol and helps to decide when the patient can return to sports activities. Isokinetic testing in our study showed that there was still some muscle weakness present at 3 and 6 months follow-up.

Agonist to antagonist ratio (H/Q ratio) could be a sign of imbalance of muscles around knee joint. Ham-strings provide knee stability as a dynamic stabilizer by preventing anterior translation of tibia. A greater difference in H/Q ratio is linked to less successful rehabilitation. Since the normal ratio is considered to be between 50-80%, while optimal ratio should be 80% [22]. Our study also showed H/Q ratio more than 50%. We noticed improved H/Q ratio between operated and non-injured leg at all measured speeds. Our measurements after 3 months showed ratio of 66% (180°/s), and at 6 months 56% and 69% respectively (60°/s and 240°/s). We also observed better values in operated leg than in healthy leg. There are studies showing that there is still significant deficit in H/Q ratios even one year after ACL reconstruction [23].

There is still some concern regarding hamstring deficit of flexor strength when harvesting both ST and GR tendons. Many studies show that hamstring tendons regenerate after ACL reconstruction [24,25], as seen on MRI studies. The study from Ardern et al. showed that hamstring strength at deep flexion angle is reduced when harvesting semitendinosus alone and also when harvesting semitendinosus and gracilis together. They noticed that clinical results, 2 years postoperatively, regarding hamstring strength, regardless of number of

hamstring harvested, were similar [26]. Adachi et al. also noticed that after hamstring harvest, their strength might be weaker at deep flexion angles [27]. Williams et al. showed that ST and GR harvest had a marked impact on semitendinosus and gracilis muscle morphology, with no clinically important impact on short-term outcomes. Also the biceps femoris and semimembranosus muscles morphology suggested their compensation for reduced semitendinosus and gracilis function [25].

The angle of peak torque is determined as the angle in joint range of motion, where peak torque is produced. The shift of the angle of peak torque increases vulnerability to injury with more eccentric loads. Our measurements of angle of peak torque at low angular velocities (60°/s) in flexion showed no statistical significance ( $p=0.24$ ) between operated and healthy leg six months postoperatively. Several studies show, that when gracilis and semitendinosus tendon are harvested, there is more loss in deep flexion angle muscle strength [27-29], weaker internal tibial rotation compared to contralateral leg [30] and it affects knee flexion isokinetic torque negatively at low angular velocity [31]. A systematic review by Sharma et al. found that gracilis harvest statistically significantly increases hamstring weakness in isokinetic testing at lower tested speeds but they believe, that it is of no clinical significance [32]. On the other hand, Yosmaoglu et al. concluded that the angle of peak torque is affected at high velocities after ACL reconstruction. They did not find any differences in the peak torque angle in knee extension at 60°/s between healthy and operated leg [33].

We measured peak torque in flexion and extension at different speeds, since deficit regarding injured to healthy leg is an indicator for muscle strength imbalance between sides. When deficit between operated and healthy leg is under 10% it is not clinically important [34]. Our deficits at 3 months were in extension 20% and in flexion 15%, meaning that there is still risk of injury and need for further rehabilitation. Testing at 6 months revealed that at 240°/s in flexion there were no clinically important differences (8%), while at 60°/s at flexion deficit was 12%. Our results show that there is a tendency toward improving deficits of peak torque in flexion and in extension (Table 3). The study from Ko et al. compared peak torques of flexor muscles 1 and 2 years after ACL reconstruction with hamstring tendons (semitendinosus and gracilis tendons). They showed flexor muscle deficit 13% and 11% 1 and 2 years postoperatively [35]. Keays et al. reported 10% hamstring deficit 6 months after reconstruction [36]. Yasuda et al. demonstrated that both hamstring harvest significantly reduces hamstring muscle strength first postoperatively year but isokinetic strength returns to the preoperative strength in 12 months [37].

The strength of our study is the prospective design, relatively big number of the patients who were included in our research and the independent observer assessment. Limitation of our study is that follow-up period is relatively short to evaluate the potential revision rate after our single bundle operation technique.

## Conclusion

Our study shows that strength of knee flexion six months after harvesting both hamstring tendons returns. However, there is still statistically significant difference in knee flexion peak torque, when comparing the operative and non-operative side. Single bundle anatomic ACL reconstruction gives excellent knee stability, good clinical results with normal knee range of motion and returning to appropriate level of activity.



## Acknowledgement

Special thanks to Rehabilitation Center Spa Zrece, Slovenia for long lasting cooperation in post-operative rehabilitation of our recreational and competitive athletes.

## Conflict of Interest

None declared.

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