

# Anterior cruciate ligament injuries treated with quadriceps tendon autograft versus hamstring autograft: A randomized controlled trial

*Lesiones de ligamento cruzado anterior tratadas con autoinjerto de tendón de cuádriceps versus autoinjerto de isquiotibiales: estudio controlado aleatorizado*

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## Abstract

**Background:** One of the most common grafts used to repair anterior cruciate ligament (ACL) rupture is the hamstring tendon (HT) autograft. However, another proposed option to repair the ACL is the quadriceps tendon (QT) autograft. This study aimed to compare the pain and clinical results between patients with ACL injury treated with QT autograft and with HT autograft. **Materials and methods:** The Ethics and Investigation Committee of our institution approved the study. The patients were randomized into two groups: one group was treated with QT autograft and the other group was treated with HT autograft. The patients were evaluated preoperatively and postoperatively using the Lysholm–Tegner score, International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, and visual analog scale (VAS), at 2 weeks and 1, 3, 6, and 12 months. **Results:** A total of 28 patients with a primary ACL injury were included in the study. No significant differences in VAS pain, Lysholm knee and Tegner activity scale scores, and IKDC score between the HT and QT groups were observed at any time point. All patients had favorable outcomes and significantly improved evaluation scores. **Conclusion:** The patients treated with QT autograft had clinical results and post-operative pain similar to those of patients treated with HT autograft for ACL reconstruction.

**Key Words:** Anterior cruciate ligament injury. Quadriceps tendon. Hamstring tendon. Lysholm score.

## Resumen

**Antecedentes:** Uno de los injertos más comúnmente usados para la reparación de una ruptura de ligamento cruzado anterior (LCA) es el autoinjerto de los tendones isquiotibiales. Sin embargo, otra opción propuesta para la reparación del LCA es el autoinjerto del tendón de cuádriceps. El objetivo de este estudio fue comparar el dolor y resultados clínicos en pacientes con lesión del LCA tratados con autoinjerto de cuádriceps y con autoinjerto de isquiotibiales. **Material y métodos:** El Comité de Ética e Investigación de nuestra institución aprobó el estudio. Los pacientes fueron aleatorizados en dos grupos: un grupo fue tratado con autoinjerto del cuádriceps y el otro grupo con autoinjerto de isquiotibiales. Los pacientes fueron evaluados preoperatoriamente y postoperatoriamente usando la escala de Lysholm-Tegner, la International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, y la Escala Visual Análoga (EVA), a las dos semanas, a 1, 3, 6 y 12 meses. **Resultados:** Un total de 28 pacientes con lesión primaria

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de LCA fueron incluidos en el estudio. No hubo diferencias significativas en EVA, escala de Lysholm-Tegner y en IKDC entre los grupos de isquiotibiales y cuádriceps durante su evaluación. Todos los pacientes tuvieron evoluciones favorables y mejoraron de forma significativa sus escalas. **Conclusión:** Los pacientes tratados con autoinjerto de tendón de cuádriceps tuvieron resultados clínicos y dolor postoperatorio similar a aquellos pacientes traídos con autoinjerto de isquiotibiales en la reconstrucción de LCA.

**Palabras Clave:** Lesión de ligamento cruzado anterior. Tendón cuádriceps. Isquiotibiales. Escala Lysholm-Tegner.

## Introduction

Anterior cruciate ligament (ACL) injury accounts for > 50% of knee traumatic lesions and has an estimated injury rate of 3000 cases/year, which makes it the most common ligament injury in the United States<sup>1,2</sup>. Isolated ACL lesions can occur in  $\leq 44.5\%$  of athletic patients, and its association with a meniscal injury can be 30-80%<sup>3-5</sup>. ACL injury occurs more commonly in women and has a relative risk of 3.96 mainly because of a variety of anatomical factors, such as weaker quadriceps and a shorter and weaker ACL in women<sup>1</sup>. One of the biggest problems with ACL-deficient knees is the instability and development of osteoarthritis, which is expected to occur in  $\leq 60-90\%$  of patients 10-15 years after the index injury<sup>6</sup>. One of the most common grafts used to repair ACL rupture is the hamstring tendon (HT) autograft, and another option is the quadriceps tendon (QT) autograft<sup>7</sup>. The QT autograft can be used to treat primary and revision ACL injuries with good results and shows better results in translation of the leg when compared with the contralateral non-injured extremity<sup>8</sup>. In a prospective evaluation over 2 years, patients treated with autologous ipsilateral QT had knee stability and functional outcomes similar to those of patients treated with contralateral semitendinosus-gracilis tendon, and no re-rupture was observed during the follow-up<sup>9</sup>.

One of the problems with ACL reconstruction is graft failure. The graft failure rate ranges from 0% to 9.5% for QT autografts and from 2.5% to 4.9% for HT autografts<sup>7</sup>. The overall graft failure rate for QT, bone-patellar tendon-bone (BPTB), and HT autografts has been estimated to be 2.8%. It has been observed that patients treated with QT autograft experience less knee laxity postoperatively than that of patients treated with HT autograft, although no significant differences were found in graft failure rates between the groups<sup>7</sup>.

The current literature suggests that QT autograft is a viable option in ACL reconstruction, with results for knee stability, functional outcomes, donor-site morbidity, and re-rupture rates comparable with those for BPTB and HT autografts<sup>10</sup>. The objective of this study

was to compare the clinical results and pain between patients with ACL injury treated with QT autograft and HT autograft.

## Materials and methods

The Ethics and Investigation Committee of our institution approved the study design. All patients provided written informed consent. This was a randomized, controlled, and single-blind clinical trial. The inclusion criteria were patients who were > 18 years of age, agreed to participate in the study, had a clinical and magnetic resonance imaging diagnosis of an ACL rupture, were with or without meniscal lesion, and had not had previous knee surgery. We excluded patients with multi-ligament lesions, osteoarthritis, chronic degenerative diseases, rheumatoid arthritis, and ACL contralateral lesion. The elimination criteria were patients lost during follow-up or voluntary requests to drop out.

The patients were randomly divided into two groups by means of a randomization plan designed with a tool available online (randomization.com). One group underwent ACL reconstruction with an autologous QT graft and the other group with an autologous HT graft. The tendon harvesting for the HT was performed through a 3 cm oblique incision medial to the tibial tuberosity following the procedure according to Petersen and Zantop<sup>11</sup>, and the QT graft was obtained following the procedure described by Rabuck et al.<sup>12</sup>

## Follow-up evaluation

The patients were evaluated preoperatively and postoperatively by the Lysholm knee score<sup>13</sup>, Tegner activity scale score<sup>14</sup>, International Knee Documentation Committee (IKDC) Subjective Knee evaluation form<sup>15</sup>, the visual analog scale (VAS), and SF-12 at baseline; 2 weeks; and 1, 3, 6, and 12 months after surgery.

## Rehabilitation

The post-operative rehabilitation protocol was the same for both groups. In the first 2 weeks, pain

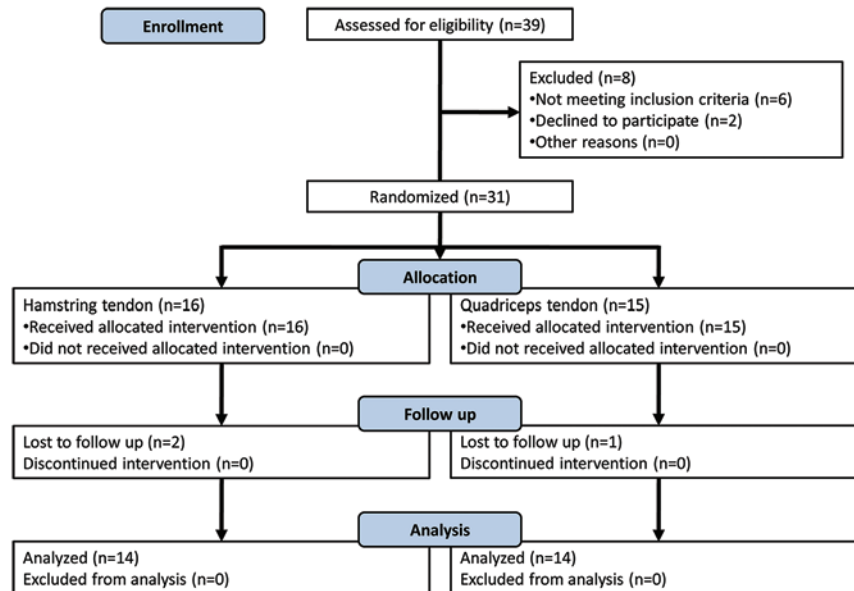


Figure 1. Flow chart of patients included.

management and anti-inflammatory measures were emphasized. The patients were allowed to walk on crutches without weight-bearing during the first 2 weeks, knee flexion was permitted up to 90°, and complete extension was allowed. From weeks 2 to 4, weight-bearing was permitted with crutch assistance. During the 1<sup>st</sup> post-operative month, knee flexion was permitted to 120°, and complete extension was allowed. In the 2<sup>nd</sup> month, closed-chain exercise was initiated, and open-chain exercise was allowed if the patient tolerated it. In the 3<sup>rd</sup> month, the open- and closed-chain exercises continued, and jogging was permitted. Finally, from 4 to 6 months, jogging was completely permitted, and the patients focused on increasing strength and muscle mass. From 6 to 8 months, return to playing sports was permitted.

### Statistical analysis

A sample of 14 participants per group was obtained using a hypothesis testing average equivalence formula, with a 95% significance level and a z beta value of 0.84 with 80% power estimating an equivalence of  $\pm 2.5$  in the Lysholm score. The demographic data of the study population were analyzed using the Mann–Whitney test and Fisher’s exact test. The normality of the distribution of the measured variables was examined using the Shapiro–Wilk test. The variables analyzed did not pass the normality test, so the Mann–Whitney test was used for between-group comparisons. The descriptive analysis consisted of

median and interquartile range or mean and standard error values. Statistical tests were performed using GraphPad Prism Software v5.00 (GraphPad Software, La Jolla, CA, USA). All data are expressed as the means  $\pm$  standard deviations, and  $p < 0.05$  was considered to be indicative of statistical significance.

## Results

### Patient demographics

A total of 28 patients with a primary ACL injury were included for final analysis. Three patients (two in the HT group and one in the QT group) were excluded from the final analysis because they did not complete their follow-up (Fig. 1). There was a higher proportion of men than women in both groups. Concomitant injuries associated with the ACL lesion were recorded in 15 (54%) cases; 6 (40%) concomitant lesions were present in the HT group; and 9 (69%) were in the QT group. The most frequent concomitant injury found was the lateral meniscus (53%). Complete patient demographics and concomitant injuries are presented in table 1.

### Clinical and functional outcomes

No significant differences in VAS pain, Lysholm score, IKDC score, and SF-12 between the HT group and QT group were observed at any time. There were statistically significant improvements in pain and knee function between the final scores and baseline scores

**Table 1. Demographic characteristics of patients in each group**

Demographics	Hamstring tendon	Quadriceps tendon	p value
Patients (n)	14	14	
Age, years (median, IQR)	23.0 (20.0-30.0)	23.0 (19.5-30.5)	0.872 <sup>a</sup>
Gender (male:female)	12:3	11:2	1.000 <sup>b</sup>
Concomitant injuries (n)	6	9	0.151 <sup>b</sup>
Medial meniscus	1	4	
Lateral meniscus	4	4	
Avulsion of the anterior tibial spine	1	1	
Affected knee (n, left: right)	10:5	8:5	1.000 <sup>b</sup>

IQR, interquartile range; <sup>a</sup>Mann-Whitney test; <sup>b</sup>Fisher's exact test.

in both intervention groups. Complete results of the VAS pain, Lysholm score, IKDC score, and SF-12 are presented in table 2.

### Flexion and extension of the knee

There was no significant difference in knee flexion/extension change from baseline at the end of the follow-up between the HT and QT groups. Both groups improved their range of motion from that at baseline; however, the difference from baseline was only significant for knee extension (HT,  $p = 0.018$ ; QT,  $p = 0.037$ ). Table 3 shows the complete measurements of knee flexion/extension.

### Discussion

Our results showed that similar outcomes were obtained with the use of a QT or an HT autograft in the reconstruction of ACL. Our patients showed similar pain levels, their evaluations showed improvement at all follow-up time points, and none of the patients had pain at the final evaluation. In a randomized comparison of pain levels and analgesic consumption after single-bundle ACL reconstruction between a QT autograft and an HT autograft in the immediate post-operative phase, it was found that most patients with QT did not require a supplementary analgesic drug, patients treated with QT autograft for ACL reconstruction had less pain in the immediate post-operative period<sup>16</sup>. Another study that evaluated the immediate

**Table 2. Clinical and functional results between the study groups**

Scale evaluated	Hamstring tendon	Quadriceps tendon	p value <sup>a</sup>
Pain (VAS)			
Baseline	4.0 (3.0-7.0)	3.0 (1.5-7.0)	0.318
12 months	0.0 (0.0-1.0)	0.0 (0.0-1.5)	0.450
p value <sup>a</sup>	< 0.0001	0.0019	
Lysholm score			
Baseline	61.0 (37.0-74.0)	75.0 (61.5-83.5)	0.062
12 months	98.0 (90.0-100.0)	95.0 (91.0-100.0)	0.828
p value <sup>a</sup>	< 0.0001	0.0004	
IKDC subjective score			
Baseline	57.0 (45.0-68.0)	57.0 (46.5-68.0)	0.818
12 months	90.0 (87.0-93.0)	90.0 (83.0-91.5)	0.505
p value <sup>a</sup>	< 0.0001	0.0001	
SF-12 physical domain			
Baseline	39.7 (37.6-44.2)	44.5 (37.1-51.6)	0.381
12 months	54.7 (51.7-55.5)	54.7 (53.2-54.7)	0.981
p value <sup>a</sup>	< 0.0001	0.010	
SF-12 mental domain			
Baseline	43.9 (31.3-50.2)	49.7 (46.6-52.0)	0.043
12 months	52.0 (52.0-53.9)	52.0 (51.1-53.9)	0.550
p value <sup>a</sup>	0.0003	0.128	

Data are presented as median and interquartile range; <sup>a</sup>Mann-Whitney test. IKDC: international knee documentation committee; VAS: visual analog scale; SF-12: 12-item short-form health survey.

**Table 3. Comparison of degree of flexion/extension of the knee**

Movement	Hamstring tendon	Quadriceps tendon	p value <sup>a</sup>
Flexion (degrees)			
Baseline	125.3 ± 1.3	126.2 ± 1.4	0.687
12 months	129.3 ± 1.4	127.3 ± 2.9	0.733
p value <sup>a</sup>	0.061	0.438	
Extension (degrees)			
Baseline	0.0 ± 0.0	0.0 ± 0.0	-
12 months	-1.7 ± 0.6	-1.9 ± 0.9	0.978
p value <sup>a</sup>	0.018	0.037	

Data are presented as mean ± standard error; <sup>a</sup>Mann-Whitney test.

post-operative pain without evaluating the analgesic requirements between BPTB autograft and HT autograft showed similar results for pain at 48 h<sup>17</sup>.

Several cohort studies have compared both techniques. In one study that evaluated 86 patients (45 patients with QT autograft and 41 with HT autograft), with a mean follow-up of  $3.6 \pm 0.4$  years, similar or better functional outcomes (Lysholm score, KOOS symptoms and function, and sports and recreational activities) were found in patients with ACL reconstruction using QT autograft<sup>18</sup>. Another cohort study that compared the use of QT autograft versus HT autograft

in a retrospective review of 48 patients with a minimum follow-up of 2 years reported significantly improved manual laxity test results in both groups after surgery; the IKDC score and Tegner activity score were better and not significantly different between the groups, the anatomical ACL reconstruction with QT showed knee stability and functional outcome scores similar to those of HT autografts, but the patients with QT autograft showed better flexor muscle strength recovery<sup>19</sup>. In another retrospective study of 72 patients with a follow-up of 24 months, similar clinical results both autografts were found<sup>20</sup>. In our study, in the evaluation of the Lysholm score and IKDC Subjective Knee Evaluation Form results, all patients showed better results during the follow-up and at the end of the evaluation, with no significant differences between groups. In the manual laxity testing, all of our patients showed negative Lachman test results during the follow-up. Similarly, knee flexion was better in both groups at the end of the study, with no significant differences between the groups. The knee extension results showed a rare outcome, with both patient groups experiencing a median loss of 2°, with significant differences between the initial and final evaluations.

The problems related to the donor site were grouped into general categories: anterior knee pain and discomfort resulting from decreased function, including range of motion and muscular strength; local discomfort caused by numbness, tenderness, or an inability to kneel; and late tissue reaction at the donor site<sup>21</sup>. Harvest of the medial HT can be complicated by injury to the neurovascular structures, tendon amputation during the harvest, tendon rupture, and a decrease in terminal knee flexion strength<sup>22</sup>. In addition, medial thigh hematoma and spasm pain are common following hamstring harvest<sup>22</sup>. Advantages of the HT graft are its high biomechanical strength, longevity, and decreased donor-site morbidity, and disadvantages are the potential development of tunnel widening and weakness of the remaining hamstrings and internal rotator musculature. Several advantages have been observed for the QT graft, including reduced incidence of anterior knee pain and decreased risk of patellar fracture relative to those of BPTB. A disadvantage in using the QT graft is the difficulty to harvest it because of the dense cortical bone, curved patellar surface, and close adherence to the suprapatellar pouch<sup>23</sup>. Anterior knee pain and weakness of the thigh were not directly evaluated in our study, only two patients complained of this possible complication (anterior knee

pain) in the QT group; however, both patients had favorable outcomes at the end of follow-up.

There were some limitations in our study, including the reduced sample size and relatively short follow-up. One of the strengths of our study is that unlike previous studies on this topic that used a retrospective cohort study design<sup>18-20</sup>, this was a randomized controlled clinical trial. In terms of the level of clinical evidence, the preferred design for a clinical trial is often a randomized controlled trial; prospective and retrospective cohort studies are ranked lower because of the biases inherent to their design. The surgical procedures were performed by two experienced surgeons in a similar way, with only very few variations between procedures. All patients completed the follow-up, were able to participate in the research, and received the same rehabilitation protocol; our results can be applied to future research. A recent systematic review stated that current literature supports the use of QT, but most of the evidence was from retrospective studies and heterogeneous patient groups. Therefore, the review suggested that further randomized controlled trials are needed to confirm their findings<sup>10</sup>.

## Conclusion

We found that the use of an autograft of QT gave outcomes for functionality, post-operative pain, and knee motion range similar to those of patients treated with HT autograft in ACL reconstruction.

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## Conflicts of interest

All authors declare non-interest conflicts with the realization and publication of this manuscript.

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## Ethical disclosures

**Protection of human and animal subjects.** The authors declare that the procedures followed were in

accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

**Confidentiality of data.** The authors declare that they have followed the protocols of their work center on the publication of patient data.

**Right to privacy and informed consent.** The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

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