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Research Article

Long Term Comparison of Hamstring Tendon Autograft and Tibialis Anterior Tendon Allograft Use in ACL Reconstruction

Zeki Gunsoy[1], Abdullah Yalcin Tabak[2], Mustafa Dinc[3], Omer Cevdet Soydemir[3]

[1]Bursa City Hospital, Department of Hand Surgery, Bursa, Türkiye
[2]Keçiören Medical Park Hospital, Department of Orthopedics, Ankara, Türkiye
[3]Bursa City Hospital, Department of Orthopedics, Bursa, Türkiye

Abstract

Aim: In the early 2000s, the optimal graft for anterior cruciate ligament (ACL) reconstruction was a subject of uncertainty. Today, autografts have become the gold standard in this procedure. Aim of this study is to contribute to the existing knowledge by conducting a comprehensive comparison of the long-term clinical outcomes between hamstring allografts and anterior tibialis tendon allografts (ATT) in the context of ACL reconstruction.
Material and Method: This study was conducted based on individuals who were operated on with the diagnosis of symptomatic ACL rupture 10 years ago. Participants were randomly assigned to undergo ACL reconstruction using either hamstring autografts or anterior tibialis allografts. All allografts were procured from a single tissue bank, underwent aseptic processing, and were fresh-frozen without terminal irradiation. Patient assessments included questionnaires based on the Lysholm knee scoring scale (LKSS) and the International Knee Documentation Committee (IKDC) subjective knee score. Objective functional tests, such as the Lachman test and pivot-shift, were performed, accompanied by a comprehensive physical examination of the knee.
Results: A total of 60 patients, comprising 58 males and 2 females, with a mean age of 29.48±6.2, were included in the study. Predominant symptoms reported were pain and giving-way phenomena. Significantly different LKSS values were observed between the preoperative and postoperative periods for both anterior tibialis allograft and hamstring autograft patients ($p<0.001$). Similarly, a significant difference was noted in the preoperative and postoperative IKDC scores for all patients ($p<0.001$).
Conclusion: Based on our research findings, both the hamstring autograft and allograft methods demonstrate success in improving LKSS and IKDC scores for patients undergoing ACL repair surgery. Notably, the autograft group exhibits a more pronounced improvement compared to the allograft group.

Keywords: Lysholm knee scoring scale, International Knee Documentation Committee score, autograft, allograft, anterior cruciate ligament reconstruction

INTRODUCTION

Anterior cruciate ligament (ACL) ruptures account for 50% of all knee joint ligament injuries. The incidence of ACL ruptures ranges between 25-78 per 100,000 individuals, with approximately 70% of these injuries attributed to sports-related activities (1-3).

Despite advancements in early detection and effective treatment options, ACL injuries persist as a significant health concern, impacting mobility and daily activities (4-6). Surgical intervention is recommended for active young athletes with specific conditions, including meniscal lesions, unstable knee joints, combined ligament injuries, and persistent pain unresponsive to non-surgical therapies (7-9). The primary objective of reconstruction is to stabilize the knee, eliminating movement restrictions within the joint. Failure to undergo reconstruction may lead to an increased risk of degenerative arthritis (10).

Various surgical techniques have been proposed in the realm of ACL injury repair. While multiple methods, including primary or supportive sutures, exist for ligament repair, anatomical reconstruction with grafting stands out as the preferred and well-established approach (11-13).

The existing literature predominantly addresses three primary grafting techniques: allograft, autograft, and synthetic grafts. Notably, synthetic grafts are infrequently utilized due to documented negative clinical and

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Corresponding Author: Zeki Gunsoy, Bursa City Hospital, Department of Hand Surgery, Bursa, Türkiye
E-mail: zekigunsoy@gmail.com

surgical outcomes (6,9,11-13). Autografts commonly utilized include those sourced from the patellar tendon, hamstring tendon, and quadriceps tendon. On the other hand, allografts undergo a series of procedures, including freezing, drying, and irradiation of the patellar tendon or tibialis anterior tendon from the donor (6).

The utilization of soft tissue grafts in ACL surgery has experienced a surge, primarily attributable to advancements in femoral and tibial fixation methods. Notably, the hamstring tendon autograft has gained popularity owing to its comparable clinical outcomes, reduced discomfort during kneeling, less anterior knee pain, diminished donor site morbidity, and a lower likelihood of injuring the extensor mechanism (14-18).

Over the past decade, there has been an increased prevalence of allograft usage in both primary and revision ACL surgery. In a study conducted by Maletis et al., allografts were employed in 42.4% of primary and 78.8% of revision ACL reconstructions, based on a community-based registry encompassing over 16,000 ACL reconstructions (19). The principal advantage of allograft tissue lies in the absence of donor site morbidity. Additional benefits include a quicker recovery period, improved aesthetics, a range of graft types and sizes, and overall reduced costs (20-23). However, allogenic tissue does pose certain risks, such as the potential for disease transmission, delayed integration, and decreased graft stiffness and strength depending on the processing method utilized with higher cost (24-26).

This study compares the long-term clinical results of anterior tibialis tendon (ATT) allografts and hamstring allografts in the setting of ACL restoration in order to advance existing knowledge.

MATERIAL AND METHOD

A cross-sectional retrospective study was conducted, involving participants diagnosed with symptomatic ACL insufficiency who underwent primary ACL reconstruction between 2008 and 2010. The study included patients who had not undergone prior surgery on the affected knee, possessed a minimum follow-up duration of 12 months, and were skeletally mature. Exclusion criteria encompassed patients with multiple ligament injuries or chondral lesions graded higher than grade 2 (Outerbridge grade 3,4) (27).

After receiving the approval of the Ethics Committee (no:E2-23-4869 date: 09/08/2023) the participants were categorized into two groups based on the type of graft used: hamstring autograft and tibialis anterior allograft. Allografts for all patients were provided by the same licensed tissue bank. These allografts underwent aseptic harvesting, were freshly frozen, and did not undergo terminal irradiation.

Operative Technique

All procedures were performed under spinal anesthesia. Patients were positioned in a supine manner on the operating table, with the knee flexed over the end of the table. The application of a pneumatic tourniquet was standard. In the Hamstring group, a longitudinal incision was made over the pes-anserinus. The semitendinosus and gracilis tendons were harvested using a closed-loop tendon stripper, and any residual muscle tissues covering the excised graft were meticulously cleansed. In the tibialis anterior group, allografts were rehydrated for 30 minutes in warm saline. The free ends were prepared using the Krakow method with Ethibond (No. 5).

Arthroscopic ACL reconstruction was performed using a trans-tibial approach. Partial meniscectomies were performed when required, graft-femoral fixation was conducted using endobutton and this approach was applied to both the hamstring autograft and tibialis anterior allograft groups. Subsequently, the knee was positioned in full extension, and the graft was securely held while a helper executed an anterior drawer technique. The graft was then anchored in place using a bioabsorbable interference screw. Additional support to the fixation was provided by the use of a ligament staple (28).

Rehabilitation

On the day of surgery, patients were equipped with an angle-adjustable knee brace, and movement during the initial postoperative week was restricted by locking the brace at 0 degrees of extension. Beginning on the first postoperative day, all patients underwent mobilization, with efforts made to push their tolerance to the extent of pain. The angle settings of the knee braces were gradually modified to facilitate 30, 60, and 90 degrees of flexion in the first, second, and third weeks, respectively. Sutures were removed from all patients during the second week, and they were uniformly referred to the same physical therapy facility to commence the rehabilitation process.

Patient Evaluation

Patients were followed for an average of 11.2±1.6years following the original procedure, and results were assessed and contrasted. The functional outcomes of the patients were evaluated using the Lysholm knee scoring scale (LKSS) and the International Knee Documentation Committee (IKDC) evaluation form. To conduct these assessments, patients' complaints and activity levels were examined at both the preoperative and final controls. A comparison of the results from preoperative and postoperative control physical examinations enabled the analysis of joint range of motion, Lachman tests, anterior drawer tests, the presence of pain at the graft extraction site, as well as surgical wound morbidity and the risk of disease transmission (29,30).

Statistical Analysis

The conformity of the data to the normal distribution was tested with the Shapiro-Wilks test. The Wilcoxon test was performed because the dependent group comparisons did not distribute the data normally. Independent group comparisons were made using the t-test if the data were normally distributed, and the Mann-Whitney test if the data were not normally distributed. The pre-post operation changes between the groups were compared by taking the difference score. Descriptive statistics were given as mean±standard deviation in case of using parametric tests, and as median (min-max) value in case of non-parametric tests. Categorical data were compared with Chi-square or Fisher's exact tests. Categorical data were given as frequency and percentage. The relationships between the variables were analyzed using the Pearson correlation coefficient in case the data showed normal distribution and the Spearman correlation coefficient in the opposite case.significance level of 0.05 or less was taken as statistical significance level. SPSS v.25 package program was used in the analysis of the data.

RESULTS

Eighty patients with ACL ruptures visited our facility once in a month and were followed remotely for an average of 11.2±1.6 years following the original procedure. Twenty patients, however, were eliminated from the study for various reasons: six refused to take part, seven were lost to follow-up, four had cartilage lesions at the time of surgery that were graded higher than II by the Outerbridge classification, two had PCL injuries, and one had a collateral ligament injury. The study included 60 patients in total—58 men and 2 women—retrospectively. Of these, thirty patients had ATT allografts used for ACL reconstruction, and the other thirty patients had hamstring autografts used for the same purpose. All patients in both groups underwent postoperative evaluations. At the time of injury, the mean age was 29.48±6.2, and the distribution of this age was similar in the allograft (30.13±5.41) and autograft (28.83±6.39) groups. Table 1 provides a summary of the homogeneity observed in the two groups. Regarding age, the LKSS, the Lachman test, the pivot-shift test, pain, and knee damage in preoperative values, no statistically significant differences were observed between the groups. However, there was a statistically significant difference between the groups as indicated by the IKDC and loosening preoperative values. The allograft group exhibited higher IKDC and loosening values in comparison to the autograft group.

Table 1. Homogeneity comparisons between groups

n (%)	Allograft (n=30)	Autograft (n=30)	p-value
Age	30.13±5.41	28.83±6.39	0.398
LKSS preop	65 (58:72)	65 (57:72)	0.888
IKDC preop	80 (70:85)	63.5 (54:71)	<0.001
Lachman test	19 (63.3)	23 (76.7)	0.260
Pivot shift test	15 (50)	9 (30)	0.114
Additional knee damage	10 (33.3)	14 (46.7)	0.292
Pain	7 (23.3)	7 (23.3)	1.000
Loosening	9 (30.0)	2 (6.7)	0.020

LKSS: lysholm knee scoring scale, IKDC: International Knee Documentation Committee

Table 2 shows the preoperative and postoperative IKDC and LKSS compressions.In both groups postoperative results of IKDC and LKSS scores were significantly better than preoperative results.

Table 2. Pre-post comparison within groups

		n	Median (Min:Max)	
Allograft group	LKSSpreop	30	65 (58:72)	<0.001
	LKSSpostop	30	94 (64:98)	
	IKDCpreop	30	80 (70:85)	0.004
	IKDCpostop	30	83 (70:89)	
Autograft group	LKSSpreop	30	65 (57:72)	<0.001
	LKSSpostop	30	96 (68:98)	
	IKDCpreop	30	63.5 (54:71)	<0.001

LKSS: lysholm knee scoring scale, IKDC: International Knee Documentation Committee

The analysis of the change in values from preoperative to postoperative in both the allograft and autograft groups yields a statistically significant difference in the scores obtained from the IKDC and the LKSS. In particular, during the switch from preoperative to postoperative exams, the LKSS and IKDC scores of the autograft group increased noticeably more than those of the allograft group (Table 3).

Table 3. Change of values in LKSS and IKDC scores between groups

	Allograft (n=30)	Autograft (n=30)	p-value
LKSS change value	26 (3:38)	30.5 (5:41)	0.006
IKDC change value	3.97±6.64	13.4±6.92	<0.001

LKSS: lysholm knee scoring scale, IKDC: International Knee Documentation Committee

Notable conclusions are drawn when comparing the scores between the two groups on the IKDC and LKSS depending on the existence of additional preoperative and postoperative injuries. (Table 4). IKDC scores in the allograft group showed a statistically significant difference among individuals who did not have additional knee injury. Similarly, preoperative and postoperative LKSS scores in the allograft group exhibited a statistically significant difference in patients with additional knee injury, with an increase observed in postoperative values compared to preoperative levels. Conversely, there was no statistically significant difference in preoperative and postoperative IKDC scores in patients with additional knee damage in the allograft group.In the autograft group, a statistically significant change was noted in preoperative and postoperative LKSS ratings among patients without additional knee injury. Postoperative values showed an increase compared to preoperative levels.

Table 4. Pre-post comparison of LKSS and IKDC scores within groups according to additional knee injury

				n	Median (Min:Max)	p-value
Allograft group	Additional knee injury (-)	preop	LKSS	20	64.5 (58:72)	<0.001
		postop	LKSS	20	94.5 (64:98)	
		preop	IKDC	20	74 (70:85)	0.013
		postop	IKDC	20	83 (70:89)	
	Additional Knee İnjury (+)	preop	LKSS	10	65.5 (63:70)	0.005
		postop	LKSS	10	93 (69:97)	
		preop	IKDC	10	82 (70:85)	0.258
		postop	IKDC	10	83 (70:87)	
Autograft group	Additional knee injury (-)	preop	LKSS	16	65.5 (57:72)	<0.001
		postop	LKSS	16	96 (68:98)	
		preop	IKDC	16	63.5 (55:68)	0.001
		postop	IKDC	16	76 (66:84)	
	Additional knee injury (+)	preop	LKSS	14	64 (59:71)	0.001
		postop	LKSS	14	96 (69:98)	
		preop	IKDC	14	63 (54:71)	0.001
		postop	IKDC	14	78.5 (65:82)	

LKSS: lysholm knee scoring scale, IKDC: International Knee Documentation Committee

Based on the change values within the allograft and autograft groups, the comparison of preoperative to postoperative LKSS and IKDC scores was examined, taking into account the existence or nonexistence of additional knee damage. The change in values between the groups is summarized in Table 5.

There was an statistically increase in IKDC and LKSS scores in all groups except IKDC scores in allograft group with pain(Table 6).

Table 5. Intergroup comparisons of LKSS and IKDC change of values according to addional knee injury status

		n	Allograft	n	Autograft	p-value
Additional knee injury (-)	LKSS change value	20	26 (4:38)	16	28 (8:41)	0.149
	IKDC change value	20	6 (-13:17)	16	13 (-2:25)	0.002
Additional knee injury (+)	LKSS change value	10	26 (3:31)	14	33 (5:38)	0.005
	IKDC change value	10	1.7±4.06	14	14.36±7.66	<0.001

LKSS: lysholm knee scoring scale, IKDC: International Knee Documentation Committee

Table 6. Preoperative-postoperative comparison within groups according to pain condition

			n	Median (Min:Max)	p-value
Allograft Group	Pain (-)	LKSSpreop	23	65 (58:70)	<0.001
		LKSSpostop	23	95 (64:97)	
		IKDCpreop	23	75 (70:85)	0.003
		IKDCpostop	23	82 (70:89)	
	Pain (+)	LKSSpreop	7	65 (63:72)	0.018
		LKSSpostop	7	92 (67:98)	
		IKDCpreop	7	82 (71:84)	0.308
		IKDCpostop	7	84 (70:87)	
Autograft Group	Pain (-)	LKSSpreop	23	65 (59:72)	<0.001
		LKSSpostop	23	96 (69:98)	
		IKDCpreop	23	63 (54:71)	<0.001
		IKDCpostop	23	77 (65:84)	
	Pain (+)	LKSSpreop	7	65 (57:71)	0.018
		LKSSpostop	7	95 (68:98)	
		IKDCpreop	7	64 (55:68)	0.028
		IKDCpostop	7	70 (66:82)	

LKSS: lysholm knee scoring scale, IKDC: International Knee Documentation Committee

A statistically significant increase was noted in the autograft group among individuals who did not experience pain when comparing the change values of the LKSS and IKDC scores between the groups based on the presence of pain. Nonetheless, when it came to people who were in pain, there was no discernible difference between the two groups (Table 7).

Table 7. Intergroup comparisons of LKSS and IKDC change according to pain status

		n	Allograft	n	Autograft	p-value
Pain (-)	LKSS change value	23	27 (3:38)	23	31 (5:38)	0.017
	IKDC change value	23	4.48±6.12	23	13.96±6.01	<0.001
Pain (+)	LKSS change value	7	24 (4:31)	7	27 (8:41)	0.209
	IKDC change value	7	3 (-13:13)	7	13 (-2:25)	0.097

LKSS: lysholm knee scoring scale, IKDC: International Knee Documentation Committee

There were no documented cases of reoperations or significant complications. Furthermore, there were no cases of infection, arthrofibrosis, or deep vein thrombosis reported in the study.

DISCUSSION

Restoring the knee to its pre-injury state is the main goal of ACL reconstruction surgery. A key factor in accomplishing this objective is the selection of the graft; a good graft should have characteristics like no morbidity at the donor site, accessibility, strength for quick healing, and instant incorporation. Our study's objective was to look into the long-term clinical results of two popular soft tissue grafts for ACL restoration in a patient population that was comparable to our own. We focused on making the graft type the only dependent variable in the research. We used the same surgical technique, femoral and tibial fixation techniques, and postoperative rehabilitation regimen for every patient in order to maintain uniformity.

Due to its advantageous characteristics, such as comparable clinical outcomes, decreased anterior knee pain and discomfort when kneeling, lower donor site morbidity, and a lower risk of potential extensor mechanism injuries, the hamstring tendon autograft has become more and more common in ACL surgery (14,16,17,22,28). Allografts, which have additional benefits like a quicker recovery time, better aesthetics, a range of graft sizes, and lower overall costs, were utilized more frequently in the 2000s for both primary and revision ACL surgery (20–23,29,30). Nevertheless, there are issues with allogenic tissue, such as the possibility of disease transmission, delayed integration, and, depending on how it is processed, decreased stiffness and strength of the graft (24, 25). Contradictory findings have been found when comparing the clinical outcomes of autografts and allografts. While some case series report no appreciable differences, others point to a higher failure rate (31,32).

The usefulness of hamstring autografting and anterior tibialis tendon allografting for ACL reconstruction was compared in this study. We utilized established metrics that are frequently used in the literature to assess the results, such as the IKDC evaluation form and the LKSS. We also looked at how preoperative pain and the existence of extra knee pathologies affected these scores. Using this method, we were able to thoroughly evaluate and compare the functional results of the two grafting techniques while taking into account significant factors like pain and related knee conditions. However, it was noted that in terms of subjective scores, hamstring autograft fared better than anterior tibialis allograft.

Previous research comparing hamstring autograft and allograft techniques in ACL reconstruction has been examined in the literature. Yang et al. (33) discovered that both methods produced comparable long-term results (mean one year) in a cohort design trial with 175 patients, even though the allograft group showed more laxity and immunologic response in the early postoperative period. With the exception of irradiated allografts, which performed similarly to autografts, another study by Grassi et al. in a meta-analysis on revision ACL reconstruction showed that autografts had better outcomes with lower laxity and complication rates than allografts (34). LKSS and IKDC values in our study significantly improved in both graft groups when compared to baseline. Interestingly, when comparing the change levels, the autograft group's improvement was more significant. More specifically, LKSS increased by 30.5 in the autograft group and by 26 in the allograft group. In terms of IKDC scores, there was a mean increase of 13.4 in the autograft group and 3.97 in the allograft group. In contrast, no differences were observed in side-to-side laxity, Lysholm, IKDC, or Tegner activity ratings at the final examination with a minimum 3-year follow-up in a study by Edgar et al. that randomly assigned 104 patients to receive either a hamstring autograft or hamstring allograft (35). The results of our study showed improvements in both groups' LKSS and IKDC scores; however, the autograft group's change in values was more noticeable than the allograft group's. We conclude that autografts outperformed allografts in patients without preoperative knee pain. There was no appreciable difference between the groups when it came to pain. Autografts performed better than allografts in patients with additional knee injuries, such as osteoarthritis and ligament damage. Notably, in terms of knee stability and clinical outcomes, Riccardo D'Ambrosi et al. found no clinical difference between autograft and allograft (36).

Every patient in our study randomly assigned to the allograft group received a fresh-frozen tibialis anterior tendon allograft from the same tissue bank. Reduced donor site hypoesthesia, enhanced cosmetics, the capacity to procure grafts of any size needed, and a reduction in stiffness in the surgical knee are just a few benefits that come with using allografts (37). The fact that there were no cases of disease transmission linked to the use of allografts in our investigation is comforting.

In a young, active group, Bottoni et al. (38) found that the use of an allograft rather than an autograft for initial ACL restoration resulted in a graft failure rate that was more than three times higher. In a similar vein, Sun et al. allocated 208 patients at random to receive a fresh-frozen hamstring allograft or an autograft of the hamstring. Despite some knees exhibiting laxity on the KT-2000 arthrometer, they did not find any overt graft failures or the need for revision in their study, which included a mean follow-up of 7.8 years (39). A different study conducted by Edgar et al. with a minimum 3-year follow-up period discovered no variation in anteroposterior laxity at the final examination (40). No graft failures were noted during the course of our investigation, which included a 13-year follow-up period. The absence of graft failures in our study could be attributed to various factors, including the exclusion of young athletes who could overstretch their grafts, the patients' sedentary lifestyles, or the patients' discontinuation of the activities that caused their ACL damage in the first place. These factors might be responsible for the good outcomes and long-term stability observed in our patient group.

There are a few significant issues with this study. The generalizability and depth of the study's conclusions may be impacted by the lack of information regarding the etiologic causes of ACL rupture and the interval between the injury and surgery. Furthermore, a small study population and a retrospective design introduce potential biases that could limit the findings' generalizability.

In order to improve the robustness and generalizability of the findings, future research could take into account addressing these limitations by implementing a prospective design, offering comprehensive details on the genesis and timing of ACL ruptures, and enlarging the study population.

In summary, this study showed that both hamstring autograft and anterior tibialis allograft produced positive long-term (10 years) clinical outcomes for ACL restoration. According to the results, the clinical outcomes, anteroposterior laxity, and failure rates of autograft and allograft are similar. It was observed, nevertheless, that hamstring autograft outperformed anterior tibialis allograft in terms of subjective scores.

CONCLUSION

It is imperative to recognize that the aforementioned conclusions are predicated upon the data at hand and the particular attributes of the population under investigation. More research with bigger and more varied patient groups is advised for a more thorough and reliable comparison. By taking these factors into account, we can gain a better understanding of the relative effectiveness and results of various graft types used in ACL reconstruction.

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REFERENCES

1. Yasen SK, Borton ZM, Eyre-Brook AI, et al. Clinical outcomes of anatomic, all-inside, anterior cruciate ligament (ACL) reconstruction. The Knee. 2017;24:55-62.
2. Nordenvall R, Bahmanyar S, Adami J et al. A population-based nationwide study of cruciate ligament injury in Sweden, 2001-2009: incidence, treatment, and sex differences. Am J Sports Med. 2012;40:1808-13.
3. Doğan Ö, Çalişkan E, Gencer B. Clinical results of single bundle anterior cruciate ligament reconstruction with hamstring autograft. Akdeniz Tıp Dergisi. 2019;5:504-9.
4. Karakoç Y, Özanlağan E. Comparison of hamstring tendon autograft and tibialis anterior allograft methods in anterior cruciate ligament reconstruction surgery: a retrospective study. Acta Oncologica Turcica. 2021;54:103-10.
5. Burnham JM, Wright V. Update on anterior cruciate ligament rupture and care in the female athlete. Clin Sports Med. 2017;36:703-15.
6. Davies GJ, McCarty E, Provencher M, Manske RC. ACL return to sport guidelines and criteria. Curr Rev Musculoskelet Med. 2017;10:307-14.
7. Vundelinckx B, Herman B, Getgood A, Litchfield R. Surgical indications and technique for anterior cruciate ligament reconstruction combined with lateral extra-articular tenodesis or anterolateral ligament reconstruction. Clin Sports Med. 2017;36:135-53.
8. Karakoç Y, Atalay İB. The role of magnetic resonance imaging and clinical assessments in predicting meniscal tear surgery. Eklem Hastalik Cerrahisi. 2019;30:85-90.
9. Muller B, Hofbauer M, Wongcharoenwatana J, Fu FH. Indications and contraindications for double-bundle ACL reconstruction. International orthopaedics. 2013;37:239-46.
10. Nordenvall R, Bahmanyar S, Adami J, et al. Cruciate ligament reconstruction and risk of knee osteoarthritis: the association between cruciate ligament injury and post-traumatic osteoarthritis. a population based nationwide study in Sweden, 1987–2009. PloS One. 2014;9:e104681.
11. Atik OŞ. Autografts or allografts for anterior cruciate ligament reconstruction?. Eklem Hastalık Cerrahisi. 2013;24:125.
12. Demirağ B, Ermutlu C, Aydemir F, Durak K. A comparison of clinical outcome of augmentation and standard reconstruction techniques for partial anterior cruciate ligament tears. Eklem Hastalik Cerrahisi. 2012;23:140-4.

13. Pujol N, Colombet P, Cucurulo T, et al. Natural history of partial anterior cruciate ligament tears: a systematic literature review. Orthop Traumatol Surg Res. 2012;98:S160-4.

14. Ahldén M, Kartus J, Ejerhed L, et al. Knee laxity measurements after anterior cruciate ligament reconstruction, using either bone–patellar–tendon–bone or hamstring tendon autografts, with special emphasis on comparison over time. Knee Surg Sports Traumatol Arthrosc. 2009;17:1117-24.

15. Biau DJ, Tournoux C, Katsahian S, et al. Bone-patellar tendon-bone autografts versus hamstring autografts for reconstruction of anterior cruciate ligament: meta-analysis. BMJ. 2006;332:995-1001.

16. Forster MC, Forster IW. Patellar tendon or four-strand hamstring? A systematic review of autografts for anterior cruciate ligament reconstruction. Knee. 2005;12:225-30.

17. Goldblatt JP, Fitzsimmons SE, Balk E, Richmond JC. Reconstruction of the anterior cruciate ligament: meta-analysis of patellar tendon versus hamstring tendon autograft. Arthroscopy. 2005;21:791-803.

18. Wagner M, Kääb MJ, Schallock J, et al. Hamstring tendon versus patellar tendon anterior cruciate ligament reconstruction using biodegradable interference fit fixation: a prospective matched-group analysis. Am J Sports Med. 2005;33:1327-36.

19. Maletis GB, Inacio MC, Funahashi TT. Analysis of 16,192 anterior cruciate ligament reconstructions from a community-based registry. Am J Sports Med. 2013;41:2090-8.

20. Caborn DN, Selby JB. Allograft anterior tibialis tendon with bioabsorbable interference screw fixation in anterior cruciate ligament reconstruction. Arthroscopy. 2002;18:102-5.

21. Cole DW, Ginn TA, Chen GJ, et al. Cost comparison of anterior cruciate ligament reconstruction: autograft versus allograft. Arthroscopy. 2005;21:786-90.

22. Pearsall AW 4th, Hollis JM, Russell GV Jr, Scheer Z. A biomechanical comparison of three lower extremity tendons for ligamentous reconstruction about the knee. Arthroscopy. 2003;19:1091-6.

23. Sherman OH, Banffy MB. Anterior cruciate ligament reconstruction: which graft is best? Arthroscopy. 2004;20:974-80.

24. Arnoczky SP. The biology of allograft incorporation. J Knee Surg. 2006;19:207-14.

25. Eagan MJ, McAllister DR. Biology of allograft incorporation. Clin Sports Med. 2009;28:203-14.

26. Genuario JW, Faucett SC, Boublik M, Schlegel TF. A cost-effectiveness analysis comparing 3 anterior cruciate ligament graft types: bone-patellar tendon-bone autograft, hamstring autograft, and allograft. Am J Sports Med. 2012;40:307-14.

27. Liu Y, Liu X, Liu Y, Yang S. Comparison of clinical outcomes of using the nonirradiated and irradiated allograft for anterior cruciate ligament (ACL) reconstruction: A systematic review update and meta-analysis. Medicine (Baltimore). 2022;101:e29990.

28. Chen L, Cooley V, Rosenberg T. ACL reconstruction with hamstring tendon. Orthop Clin North Am. 2003;34:9-18.

29. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res. 1985:43-9.

30. Höher J, Münster A, Klein J, et al. Validation and application of a subjective knee questionnaire. Knee Surg Sports Traumatol Arthrosc. 1995;3:26-33.