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Graft choice to decrease the revision rate of anterior cruciate ligament reconstruction: a nationwide retrospective cohort study

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There are many graft choices for anterior cruciate ligament (ACL) reconstruction, including autografts and allografts. The choice of graft has been identified as a significant factor affecting the outcome of ACL reconstruction. This study aimed to determine whether allograft or autograft is better for avoiding revisional ACL reconstruction. The National Health Insurance Service-Health screening database analyzed 146,122 patients who underwent ACL reconstruction surgery from Jan. 1, 2002, to Dec. 31, 2021. The study was conducted in two groups, autograft or allograft, and the rates of revision ACL reconstruction between the two groups were compared. Propensity score matching and multivariable Cox Proportional Hazard model analysis were used. The significant predictors for complications ($p < 0.05$) were as follows. The total of patients with ACL reconstruction was 146,122. Allograft was used in 121,148 patients, and autograft was used in 24,974 patients. 9.2% of the allograft group and 8.7% of the autograft group underwent revision ACL reconstruction. ($P < .0001$) 70.0% & 63.6% of patients underwent revision surgery within 1 year in the allograft & autograft groups, respectively. In summary, using autograft in primary ACL reconstruction is helpful in lowering the rate of revision surgery.

Abbreviation

ACL Anterior cruciate ligament

Anterior cruciate ligament (ACL) injuries are among the most common knee injuries, especially in sports-related activities. Surgical reconstruction of the anterior cruciate ligament (ACL) with graft is mostly indicated in cases of ACL rupture to restore stability and prevent the arthritic change of the knee joint, as the natural healing capacity of ACL is still questionable. While several graft options are available for ACL reconstruction, the choice of graft is critical as it can affect the outcome of the surgery. The most commonly used grafts for ACL reconstruction are autografts and allografts. Autografts are harvested from the patient's body, while allografts are obtained from a donor.

There are many previous studies comparing allograft and autograft in ACL reconstruction. There is no significant difference between autograft and allograft tendons in clinical outcomes such as functional and clinical scores¹. In radiologic outcomes such as following MRI or second look arthroscopy, autograft tendon showed slightly better outcomes^{2,3}. However, there is no study on the revision rate according to the type of graft in big data of mature patients. This study aimed to determine whether allograft or autograft is better to avoid revision reconstruction.

Despite the high success rate of ACL reconstruction surgery, there is still a considerable failure rate. A recent long-term cohort study reveals that the failure rate of ACL reconstruction is about 9% at 25 years following⁴. Failure of ACL reconstruction can result in instability, pain, and the need for revision surgery. Several factors can

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contribute to the failure of ACL reconstruction, such as patient age, activity level, and surgical technique. However, the choice of graft has been identified as a significant factor affecting the outcome of ACL reconstruction.

Therefore, we aim to review and analyze the available literature on the failure rate according to graft choice for ACL reconstruction. Specifically, this paper will compare the failure rates of autografts and allografts and identify the factors that contribute to the failure of the graft. By doing so, this paper will provide valuable insights into selecting the most appropriate graft for ACL reconstruction, which can help improve the success rate of this surgical procedure.

Results

Patient demographics

From 2003 to 2021, 146,122 patients underwent ACL reconstruction were found in South Korea. Table 1 shows the total number of cases of ACL reconstruction per year according to graft. The number of patients undergoing ACL reconstruction has increased over the years from 513 in 2003 to 8,921 in 2021. The usage of allograft and autograft increased at a similar rate. Allograft and autograft were used in 121,148 cases (82.9%) and 24,974 cases (17.1%), respectively. (Table 1.) There were no differences in age and sex after propensity score matching. (Table 2.)

Revision rate

Of the 146,122 patients who underwent ACL reconstruction, 13,273 patients (9.1%) underwent revision ACL reconstruction. Compared to females, the revision rate of ACL reconstruction in males increased significantly. (P -value < 0.0001) 11,091 patients out of a total of 116,021 patients (9.6%) performed revision surgery in the male group. However, only 2182 patients among 30,101 patients (7.2%) underwent revision reconstruction in the female group. As age increased, the rate of revision surgery decreased significantly. (P -value < 0.0001)

		Population				<i>p</i> -value*
		Allograft		Autograft		
		N	%	N	%	
Total		121,148		24,974		
Sex	Male	94,935	78.4%	21,086	84.4%	<.0001
	Female	26,213	21.6%	3888	15.6%	
Age	<20	15,006	12.4%	3712	14.9%	<.0001
	20–39	60,901	50.3%	14,775	59.2%	
	40–49	24,911	20.6%	4430	17.7%	
	50–59	15,786	13.0%	1773	7.1%	
	Over 60	4,544	3.8%	284	1.1%	
Revision		11,102	9.2%	2171	8.7%	0.0184
Less than 1 year		7,776		1381		
Over 1 year		3,326		790		

Table 1. The total number of cases of ACL reconstruction per year according to graft.

		After 1:1 Propensity Score Matching (PSM) by sex and age group				
		Allograft		Autograft		<i>p</i> -value*
		N	%	N	%	
Total		24,974		24,974		
Sex	Male	21,086	84.4%	21,086	84.4%	1.0000
	Female	3888	15.6%	3888	15.6%	
Age	<20	3712	14.9%	3712	14.9%	1.0000
	20–39	14,775	59.2%	14,775	59.2%	
	40–49	4430	17.7%	4430	17.7%	
	50–59	1773	7.1%	1773	7.1%	
	Over 60	284	1.1%	284	1.1%	
Revision		2689	10.8%	2171	8.7%	<.0001
Less than 1 year		1893	70.4%	1381	63.6%	
Over 1 year		796	29.6%	790	36.4%	

Table 2. Propensity score matching by sex and age group. The *p*-value tests the difference between the ratio of outcome between allograft and autograft.

16.8% of patients (3148 out of 18,718) underwent revision surgery at the age of under 20. However, at over 60, only 2.7% of patients (132 among 4828) performed revision surgery (Table 3.) After propensity score matching, the patients' demographics showed a reoperation rate of 10.0% among men and 8.4% among women, showing statistical significance. Regarding age, 17.3% of people in their 20 s and 9.6% of those aged 20–39 showed reoperation, and 4.3% of people in their 50 s showed reoperation rates, statistically significantly higher in younger patients (Table 4).

As a result of analyzing the risk factor of revisional ACL reconstruction, autograft had a lower hazard ratio than allograft according to graft type. And the risk of ACL reoperation was high in men and under 20 s. (Table 5.) Considering the hazard ratio of allograft compared to autograft, the HR was clearly higher at 1.436 when using the model considering the time of outcome occurrence. The risk of revision in the group using allograft was higher than autograft when gender and age were matched. (Table 6).

	Total	Revision ACL reconstruction		
		N	(%)	<i>p</i> -value*
Sex				
Male	116,021	11,091	9.6%	<.0001
Female	30,101	2182	7.2%	
Age				
<20	18,718	3148	16.8%	<.0001
20–39	75,676	7503	9.9%	
40–49	29,341	1687	5.7%	
50–59	17,559	803	4.6%	
Over 60	4,828	132	2.7%	
Total	146,122	13,273	9.1%	

Table 3. Patients demographics who underwent revision ACL reconstruction.

	Total	Revision		
		N	%	<i>p</i> -value
Sex				
Male	42,172	4205	10.0%	<.0001
Female	7776	655	8.4%	
Age				
<20	7424	1285	17.3%	<.0001
20–39	29,550	2849	9.6%	
40–49	8860	551	6.2%	
50–59	3546	152	4.3%	
Over 60	568	23	4.0%	

Table 4. Patients who underwent revisional ACL reconstruction after propensity score matching.

Risk factor		Revision			<i>P</i> -value
		HR*	95% C.I		
			Lower	Upper	
Graft type	Autograft	1.000			
	Allograft	1.287	1.229	1.348	<.0001
Sex	Male	1.000			
	Female	0.865	0.825	0.906	<.0001
Age	<20	1.000			
	20–39	0.542	0.519	0.565	<.0001
	40–49	0.294	0.277	0.312	<.0001
	50–59	0.253	0.234	0.274	<.0001
	Over 60	0.175	0.147	0.208	<.0001

Table 5. Risk factors of revision ACL reconstruction.

Risk factor		Revision			
		HR*	95% C.I		p-value
			Lower	Upper	
Graft type	Autograft	1.000			
	Allograft	1.436	1.342	1.537	<.0001

Table 6. Risk factors of revision ACL reconstruction after propensity score matching. HR: Hazard ratio, A model considering the time until an outcome occurs(month).

Timing of revision surgery

We analyzed the timing of the surgery by dividing it into 1 year. In the allograft group, 7776 patients among 11,102 patients (70%) underwent revision surgery within 1 year. We found similar figures in the autograft group: of the 2171 patients, 1381 patients (63.6%) underwent revision reconstruction within 1 year. (Table 7.) There was no significant difference between the two groups.

Discussion

The choice of graft material is one of the critical factors affecting the outcome of ACL reconstruction⁵. In this paper, we reviewed the current literature on the failure rates of different graft options for ACL reconstruction and provided a comprehensive analysis of the available evidence. This study was a long-term analysis from 2003 to 2021, and it was possible to find the difference in the risk of revision surgery in ACL reconstruction patients by graft type.

Among all patients receiving ACL reconstruction, graft failure remains an uncommon but devastating outcome with an estimated graft survival rate of 91% at 25 years following⁴. Among the autograft options, the hamstring graft and patellar tendon graft have been widely used and are associated with relatively low failure rates, ranging from 1 to 8%. The quadriceps tendon graft is a newer option that has shown promising results in recent studies, with failure rates similar to those of hamstring and patellar tendon grafts⁶. Allograft options for ACL reconstruction include the Achilles tendon and tibialis anterior tendon, among others. occurrence after propensity score matching. The use of allografts has also been associated with an increased risk of disease transmission and immune reactions^{7,8}.

Graft synovialization has some benefits in ACL reconstruction. As most mechanoreceptors of the ACL are present in the synovial layer, synovialization is known to recover proprioception⁹. Also, synovialization of ACL grafts subsequently makes a larger volume, this could be related to superior biomechanical stability. According to previous studies, autograft is more beneficial than allograft for synovialization¹⁰. According to this, autograft is theoretically more stable than allograft.

However, conflicting results have been published recently regarding the rate of revision. According to a few papers, allografts have been associated with higher failure rates compared to autografts. A prospective study by van Eck et al. reported a 13% failure rate after ACL reconstruction with an allograft¹¹. Vishal M. Mehta et al. compared BPTB autograft and allograft in ACL reconstruction and reported that a higher rate of revision reconstruction was associated with the use of allograft during primary ACL reconstruction¹². Contrary to this, Gerwin Haybac et al. reported that the type of graft does not affect the failure rate in ACL reconstruction¹³. Also, Ian et al. reported that skeletally immature patients have no statistical significance in the revision rate according to graft choice¹⁴.

According to previous studies, 10% of patients with ACL reconstruction underwent revision surgery in the US. In South Korea, about 9% of patients underwent revision surgery, similar to the US. In the US, about 80% of patients used autograft tendons in ACL reconstruction surgery. However, only 20% of autograft tendons in South Korea were used. Statistically, the autograft tendon is mainly used worldwide. This stems from differences in the healthcare system.

In many previous studies, young age has been reported to be associated with a low graft failure rate. Younger age & higher activity level were predictors of increased odds of graft failure¹⁵. This was also seen in our results. As the age decreased, the rate of revision surgery increased, and the highest revision rate was observed under the age of 20. According to a recent retrospective study of ACL reconstruction using the hamstring tendon, the young male showed a higher risk of graft failure¹⁶. However, Christine M Etzel et al. reported that sex is not considered

	Allograft		Autograft		p-value*
	N	%	N	%	
Total	121,148		24,974		
Revision	11,102	9.2%	2171	8.7%	0.0184
Less than 1 year	7,776	70.0%	1381	63.6%	
Over 1 year	3,326	30.0%	790	36.4%	

Table 7. Timing of revision ACL reconstruction.

a risk factor for ACL graft failure rate in a systematic review¹⁷. According to our data, the rate of revision surgery was higher in males than in females. This trend could be related to higher activity levels.

We found that 70.0% of patients with revision ACL reconstruction underwent surgery within 1 year of primary reconstruction. Kate E Webster et al. reported that almost half (47%) underwent revision surgery within the first postoperative year, and 74% occurred within the first 2 years¹⁸. Revision surgery within a year is likely to have occurred mainly due to technical problems or wrong rehabilitation. Revision after a year seems to have been caused by re-injury. However, no significant difference was observed between the two groups over time of revision surgery. We can infer from this that there is no difference in the cause of revision according to the graft choice.

Our review found that the failure rates of different graft options for ACL reconstruction vary depending on graft choices. We found that autograft significantly reduces the revision rate in ACL reconstruction. The choice of graft material for ACL reconstruction should be based on several factors, including the patient's age, activity level, comorbidities, and the surgeon's experience and preference. The long-term outcomes of ACL reconstruction with different graft options had been unclear, and failure rates of different graft options for ACL reconstruction reported in the literature are based on various study designs, making it difficult to compare results across studies. According to our nationwide study, we could overcome these problems and suggest criteria for selecting grafts in ACL reconstruction.

Our study has a few limitations. First, we used different allograft or autograft choices. There might be some differences between graft options. Second, this data was not collected by a single surgeon or institute. There could be some differences in surgical methods between surgeons. Third, we haven't considered other variables such as age and sex. There might be some errors accordingly.

Conclusion

The choice of graft material for ACL reconstruction is a complex decision that should be made based on multiple factors. The revision rate of ACL reconstruction was relatively high for younger age, male, and allografts. Our study shows that using autograft can be advantageous in lowering the rate of revision in ACL reconstruction. However, further research is needed to determine the optimal graft choice for ACL reconstruction.

Materials and methods

This retrospective cohort study uses customized data provided by the National Health Insurance Service (National Health Insurance Service-HealthScreening; NHIS-HealS)^{19,20}. This study used NHIS-NSC data from the National Health Insurance Service (NHIS)^{19,20}. The Institutional Review Board of National Health Insurance Service Ilsan Hospital (NHIMC 2023-03-024) approved this retrospective Health Insurance Portability and Accountability Act-compliant cohort study and waived the informed consent from the participants, because this study was expected to present no or minimal risk of harm to the participants, and all the data used were anonymized^{19,20}.

All methods were performed in accordance with relevant guidelines and regulations^{19,20}. The authors alone are responsible for the content and writing of the paper. This study used NHIS-NSC data (NHIS-2023-1-259) made by the National Health Insurance Service (NHIS). Korea has an obligatory National Health Insurance system with universal coverage^{19,20}. NHIS-HealS database has reimbursement records from all medical institutions in Korea^{19,20}. The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request. The authors alone are responsible for the content and writing of the paper^{19,20}.

The National Health Insurance Service-Health screening database analyzed 146,122 patients who underwent ACL reconstruction surgery from Jan. 1, 2002, to Dec. 31, 2021.

Among patients diagnosed with ACL injury (diagnostic codes: S83.50, S83.52, M23.53, M23.63, M23.83, M23.93, M23.01, M23.11, M23.21, M23.31, M23.41, S83.7), patients who underwent ACL reconstruction (N0880, N0881) from Jan. 1, 2003 to Dec. 31, 2021 were included in the study. We excluded patients who underwent additional reconstruction, such as posterior cruciate ligament, lateral collateral ligament or medial collateral ligament. Two groups could be distinguished because specific codes (N0911 and N0310) were used in the autograft group.

Propensity score matching was calculated based on age, sex, and type of grafts, and the propensity score matching matched 21,806 male and 3,888 female patients in each group. The p-value tests the difference between the outcome ratio between allograft and autograft.

For all analyses, SAS 9.4 (SAS Inc., Cary, NC, USA) was used for all analyses. Multivariable Cox Proportional Hazard model analysis was used for eight independent variables of postoperative complications. And a model considering the time until an outcome occurs (month) was used. In the case of complications and hospital-related variables, there were no missing data due to the nature of the claim data. Cases in which patient-related variables were missing due to information errors were extremely rare and these were excluded. HR and 95% confidence interval (CI) are presented. The level of significance was maintained with a *P* value < 0.05.

Data availability

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

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Author contributions

Conceived and study design: S.H.P., J.H.M. Analysed the data: S.H.P., J.H.M., T.Y Prepared the table: J.H.M., T.Y., S.H.P. Interpreted data: J.H.M., S.H.P. T.Y., H.C.O. Reviewed and approved the final manuscript: J.H.M., H.K.Y., H.C.O., T.Y., S.H.P.

Competing interests

The authors declare no competing interests.

Additional information

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