Original article
https://doi.org/10.18019/1028-4427-2025-31-5-567-573

ACL reconstruction: correlation of the functional outcome with the position of femoral and tibial tunnels

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Abstract

Introduction The anterior cruciate ligament (ACL) is the main ligament that stabilizes the knee and stops anterior translation. It is also essential to the screw-home mechanism and helps resist valgus and rotational stress. For ACL reconstruction, autograft arthroscopic single-bundle surgery is regarded as the "gold standard" procedure. Joint laxity is enhanced and cartilage degradation is avoided with anatomical ACL restoration. Negative results are frequently caused by technical surgical errors, such as improper tunnel placement.

This study **aims** to evaluate the functional outcome in ACL-reconstructed patients when a graft is placed in an anatomical position, as well as to compare it with when a graft is placed in a non-anatomical place.

Methodology This is a 24-month prospective observational study conducted on 44 patients who underwent arthroscopic ACL reconstruction, with post-op CT scans performed after permission from the institutional review board (IRB). The most common mode of injury was sports-related. Thirty patients belonged to the anatomical group, and 14 patients belonged to the non-anatomical group based on inclusion and exclusion criteria. The Lysholm scoring system was used for functional evaluation on follow-up at three, six, and 12 months.

Results The mean Lysholm score was 41.24 before surgery for the entire sample. In the anatomical group, the score improved to 80.91 at three months, 85.91 at six months, and 89.23 at twelve months. In the non-anatomical group, the score was 58.58 at three months, 65.13 at six months, and 58.58 at twelve months. The improvement in Lysholm scores in the anatomical group was statistically significant.

Conclusion This study concludes that the functional outcome of ACL reconstruction is better when the graft is placed in anatomical footprints than when it is placed in non-anatomical footprints.

Keywords: Femoral tunnel, tibial tunnel, ACL reconstruction, anatomical grafting, Lysholm score

For citation: Shinde MB, Patel MR, Sarwey K, Jethlia S, Kaulgud V, Datta R, Modi A, Kharate S, Singh S, Bopardikar T, Beniwal V, Chiwadshetti Sh. ACL reconstruction: correlation of the functional outcome with the position of femoral and tibial tunnels. *Genij Ortopedii*. 2025;31(5):567-573. doi: 10.18019/1028-4427-2025-31-5-567-573.

Научная статья
УДК 616.758.3-072.1]-089.168
https://doi.org/10.18019/1028-4427-2025-31-5-567-573

Реконструкция передней крестообразной связки: корреляция функционального результата с положением бедренного и большеберцового каналов

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Аннотация

Введение. Передняя крестообразная связка (ПКС) является основной связкой, стабилизирующей колено и предотвращающей смещение голени вперед. Ее роль существенна в механизме винтовой фиксации, который помогает противостоять вальгусной и ротационной нагрузкам. Однопучковая артроскопическая аутопластика считается «золотым стандартом» при реконструкции ПКС, в результате которой стабилизируется сустав и предотвращается дегенерация хряща. Отрицательные результаты часто вызваны техническими ошибками во время операции, такими как неправильное положение канала для трансплантата.

Цель работы — сравнительная оценка функциональных результатов у пациентов с реконструкцией ПКС при помещении трансплантата в анатомическое и неанатомическое положения.

Материал и методы. Данное 24-месячное перспективное наблюдательное исследование проведено на 44 пациентах, которым выполняли артроскопическую реконструкцию ПКС и послеоперационное КТ-исследование. Пациенты разделены на две группы: группа с анатомическим положением трансплантата (30 пациентов) и группа с неанатомическим положением трансплантата (14 пациентов). Наиболее распространенным видом травмы была спортивная травма. Для функциональной оценки при контроле через три, шесть и 12 месяцев использовали оценочную шкалу Lysholm.

Результаты. Средний балл по Lysholm до операции составил 41,24 для всей выборки. В анатомической группе общий балл улучшился до 80,91 через три месяца, до 85,91 через шесть месяцев и до 89,23 через двенадцать месяцев. В неанатомической группе показатели составили соответственно: 58,58, 65,13 и 58,58 баллов. Улучшение суммы баллов по шкале Lysholm в анатомической группе было статистически значимым.

Заключение. Артроскопическая реконструкция ПКС имеет лучший функциональный результат при помещении трансплантата в анатомическое положение по сравнению с неанатомическим положением.

Ключевые слова: бедренный канал, большеберцовый канал, реконструкция ПКС, анатомическая трансплантация, оценка Lysholm

Для цитирования: Shinde M.B., Patel M.R., Sarwey K., Jethlia S., Kaulgud V., Datta R., Modi A., Kharate S., Singh S., Bopardikar T., Beniwal V., Chiwadshetti Sh. Реконструкция ПКС: корреляция функционального результата с положением бедренного и большеберцового каналов. *Гений ортопедии*. 2025;31(5):567-573. doi: 10.18019/1028-4427-2025-31-5-567-573.

INTRODUCTION

The anterior cruciate ligament (ACL) is the most frequently injured ligament, while the knee is the most frequently injured joint overall. The knee's main stabilizer, the ACL, stops the knee from anterior translation. Additionally, it plays a crucial role in reducing valgus and rotational stress and plays an important role in the screw home mechanism. Depending on the demography, the annual incidence rates of ACL injuries range from 30 to 40 ruptures per 100,000 people [1]. Incidence is more common in sports players. From the initial primary repair to extracapsular augmentation and tendon graft-based ACL reconstructions, surgical treatment of ACL-deficient knees has advanced. For ACL reconstruction, autograft arthroscopic single-bundle surgery is regarded as the "gold standard" [2]. Reconstruction of a ruptured ACL is a well-established procedure [3]. Restoring proper knee joint function and preventing the onset of secondary osteoarthritis are the goals of ACL restoration [4].

Up to 25 % of patients still do not achieve adequate function following an ACL repair, despite advancements in surgical procedures over the previous few decades [5]. One of the main difficulties in reconstructing the anterior cruciate ligament is the placement of anatomical grafts. Joint laxity is enhanced and cartilage degradation is avoided with anatomic ACL restoration [6]. These days, anatomical graft placements should be prioritized in ACL restoration to replicate normal physiologic graft tension and more precise knee kinematics [7]. Technical surgical errors, such as incorrect tunnel placement, are a common cause of poor outcomes [8]. The most frequent technical mistake that results in graft failure is tunnel misplacement; femoral tunnels positioned too anteriorly seem to be the most crucial of these mistakes [9]. It is estimated that up to 80 % of technical failures are based on improper tunnel placement [10]. Currently, the most effective technique to assess the proper positioning of the ACL tunnel and graft is three-dimensional (3D) reconstruction of computed tomography (CT) images [11–12].

Tunnel diameter, tunnel length, femur diaphyseal angle (coronal angle/coronal obliquity), and tunnel position utilizing the Bernard and Hertel grid are the usual anatomical parameters for the femoral tunnel [13]. Tunnel diameter, tunnel length, anteroposterior and mediolateral tunnel position using the quadrant technique, coronal angle, and sagittal angle are among the anatomical factors for a reconstructed tibial tunnel [14].

The Lysholm scoring method is widely used to assess functional results in knee joints [15]. Theoretically, ACL reconstruction with a non-anatomical graft may impair knee joint stability and kinematics. This non-anatomical reconstruction can potentially alter the functional outcome of an ACL reconstructed knee.

This study **aims** to evaluate the functional outcome in ACL-operated patients when a graft is placed in an anatomical position, as well as to compare it with when a graft is placed in a non-anatomical place.

MATERIALS AND METHODS

This is a 24-month prospective observational study of 44 patients with anterior cruciate ligament (ACL) tears that have been identified and operated on. The institutional ethics (Institutional Review Board — IRB) committee provided approval. Data were gathered using the clinical history proforma, and patient information was documented at a tertiary care facility. The study comprised patients who presented to the orthopaedic department using predetermined inclusion and exclusion criteria.

The study comprised patients with solitary ACL injuries, ACL tears with or without accompanying meniscus injuries (single cruciate ligament damage), fused epiphysis, average body mass index (18.5–24.9 kg/m^2) and age ranging from 20 to 50 years. Patients with open injuries, associated posterior cruciate ligament injury, medial or lateral collateral ligament injuries, ACL re-injury, ipsilateral lower limb fractures around the knee, refusal to undergo a postoperative CT scan, and prior surgery on or around the same knee were excluded. Patients who volunteered to participate in the trial provided signed informed consent.

Preoperative evaluation involved an assessment of general health and a thorough examination of the affected knee. Radiographic evaluation included anteroposterior and lateral views as well as MRI of the affected knee. All patients underwent arthroscopic ACL reconstruction using a hamstring graft, performed by a senior consultant. Careful attention was given to the preparation of the graft, tunnel creation in the tibial and femoral regions, and secure fixation of the graft in the anatomical position. In the postoperative period, a CT scan of the operated limb was performed to check for anatomical graft placement.

The anatomical parameters used to assess graft placement were:

Femur

— Tunnel diameter;

— Tunnel length;

— Femoral diaphyseal angle (coronal angle/coronal obliquity);

— Tunnel position using the Bernard and Hertel grid.

Tibia

— Tunnel diameter;

— Tunnel length;

— Anteroposterior and mediolateral tibial tunnel position using the quadrant approach;

— The coronal and sagittal angles.

Based on these parameters, patients were categorized into two groups: anatomical (femoral and tibial tunnels in the anatomical position) and non-anatomical (femoral or tibial tunnel not in anatomical position). All the patients in both groups had no difference in an average BMI.

Outcome measures: Functional outcomes were assessed using the Lysholm score preoperatively, at three months, six months, and 12 months postoperatively. This scoring mechanism assumed a pivotal role, serving as a critical instrument in providing an intricate and in-depth assessment of the overall knee function and symptomatology experienced by individuals undergoing ACL reconstruction.

Statistical Analysis: A case record (PROFORMA) was filled out by an investigator using the interview technique. The collected data were tabulated in an Excel sheet under the guidance of a statistician. Means and standard deviations of the measurements per group were used for statistical analysis (SPSS 22.00 for Windows; SPSS Inc., Chicago, USA). The difference between the two groups was assessed using the chi-square test, with the level of significance set at $p < 0.05$.

RESULTS

The study included 44 patients of which 36 were male and eight were female. The mean age of participants was 28 years and the right side was more commonly injured than the left. The most common mechanism for the injury was sports-related. Out of 10 patients with meniscus injury, five patients belonged to each group, and there was no statistically significant difference between the groups (Table 1).

Table 1

Demography

		Group of anatomical graft placement (*n* = 30)	Group of nonanatomical graft placement (*n* = 14)	*P* value	Statistical significance
Age (Mean)		x ± x = 28.2 years	x ± x=27.7 years	0.176	No
Male	*n*	26	10	0.0000243	Yes
	%	87	71		
Female	*n*	4	4		
	%	13	29		
Bone Mass Index (Mean)		23.1± 2.6	23.5± 3.2	0.687	No
Site Right	*n*	23	7	0.0159	Yes
	%	77	50		
Site Left	*n*	7	7		
	%	23	50		
Mechanism of injury — sports	*n*	24	9	0.0000000294	Yes
	%	80	64		
Mechanism of injury — road traffic accidents	*n*	5	2		
	%	17	14		
Other mechanism	*n*	1	3		
	%	3	22		

In the anatomical group, preoperatively almost all patients had lower Lysholm scores. Post-operatively, the number of patients with improved Lysholm scores increased from 13 patients (43 %) at three months to 26 patients (87 %) at 12 months. None of the patients showed poor scores at 12 months. This improvement was statistically significant (Table 2). Pre-operatively, none of the patients had an excellent Lysholm score. The number of patients with an excellent and good score increased in the postoperative period for the anatomical group while the number of patients with fair and poor scores remained the same even at 12 months post-operatively. This improvement in the number of patients in the anatomical group was statistically significant.

The mean Lysholm score was 41.24 before surgery in the entire sample of patients. In the anatomical group, this score improved significantly at six months, as well as at twelve months. In the non-anatomical group, the score remained the same at twelve months. The improvement in Lysholm scores in the anatomical group was statistically significant (Table 3).

Table 2

Comparison of Lysholm scores

Lysholm score	Group of anatomical graft placement (n = 30)		Group of nonanatomical graft placement (n = 14)		P value
	n	%	n	%	
Pre-op					
Excellent (91–100)	0	0	0	0	0.553
Good (84–90)	2	7	0	0	
Fair (65–83)	10	33	6	43	
Poor (< 65)	18	60	8	57	
3 months					
Excellent (91–100)	4	13	0	0	0.0075
Good (84–90)	9	30	0	0	
Fair (65–83)	15	50	6	43	
Poor (< 65)	2	7	8	57	
6 months					
Excellent (91–100)	12	40	0	0	0.0000247
Good (84–90)	10	33	2	14	
Fair (65–83)	8	27	4	29	
Poor (< 65)	0	0	8	57	
12 months					
Excellent (91–100)	17	57	0	0	0.000000603
Good (84–90)	9	30	0	0	
Fair (65–83)	4	13	8	57	
Poor (< 65)	0	0	6	43	

Table 3

Lysholm score in the groups

Position	Lysholm score			P value
	3 months	6 months	12 months	
Anatomical	80.91	85.91	89.23	< 0.05
Non-anatomical	58.58	65.13	58.58	

Only two patients from our study had swelling, one patient had a stiff knee and one patient had infection. The patients with post-op swelling and stiff knees were managed with physiotherapy and infection was treated with antibiotics.

DISCUSSION

These days, ACL tears are frequent injuries due to rising participation in sports and an increase in traffic accidents. Despite debate over whether ligament restoration is necessary for all individuals with ACL injuries, arthroscopic surgical reconstruction has emerged as the preferred course of treatment. Restoring knee stability is the main objective of this surgery, which enables the patient to resume a normal range of motion and engage in sports. Restoring normal knee kinematics and avoiding early arthritic alterations are additional goals. For ACL reconstruction, hamstring (semitendinosus and gracilis) tendon autograft is currently the recommended option. The purpose of our study was to compare the functional results of patients undergoing ACL restoration in anatomical footprints and those in non-anatomical footprints.

The mean age of the patients in our study was 28 years, and it ranged from 20 to 55 years. Most of the patients were between the ages of 25 and 35. Nine female patients and thirty-five male patients participated in this study. The prevalence of ACL injuries in men may be explained by the fact that men participate in sports and outdoor activities at higher rates than women. Patients' age ranged from 17 to 48 years, with a mean age of 26.3 years and a median age of 25.0 years, according to a series of studies by J.L. Johnson et al. [16]. The majority of the patients in their study were between the ages of 15 and 25, including 23 (92 %) men and two (8 %) girls.

Sports-related injuries accounted for 33 (75 %) and traffic accidents for seven (15.90 %) cases of the injuries in our study. Football and athletic activities were the most prevalent sports-related injuries. The increased participation in sports activities may be the cause of the variation in the manner of injury. Twenty-five individuals

with ACL deficit, ages 17–43, with an average age of 25.8 years, participated in a study by X. Li et al. [17]. It discovered that sports accounted for 68 % of the injuries, falls accounted for 24 %, and motor accidents accounted for 8 % of cases.

Thirteen individuals (31.81 %) in our study had left knee involvement, while thirty patients (68.18 %) had right knee involvement. In their study, A.M. Tayeb et al. [18] found that left-sided ACL injuries were less common (37.5 %), right-sided injuries accounted for the majority (62.5 %).

ACL tears were the most frequent main diagnosis in our study. Ten instances (22.2 %) had medial meniscus injury, and three cases (6.67 %) had lateral meniscus injury, for a total of thirteen patients (28.89 %) with combined meniscal injury and ACL tear. If a meniscal tear was discovered during surgery, a meniscectomy was carried out. ACL injuries were isolated in the 32 individuals (71.11 %) that remained. In their analysis of 107 patients, M. Kruger-Franke et al. [19] discovered that ACL ruptures were linked to 45 % of medial meniscus ruptures and 55 % of lateral meniscus tears.

Of 44 patients, 30 had anatomical graft placement (68.18 %), while 14 had non-anatomical graft placement (31.81 %). We used a 3D CT scan to check the post-operative anatomic placement of the reconstructed ACL. M. Kim et al. [5] and A.P. Parker et al. [20] also used a CT scan to check the anatomical placement. Femoral and tibial tunnel length and diameter, femoral diaphyseal angle, tunnel, and tunnel position using the Bernard and Hertel grid (femur) and quadrant method (tibia), as well as coronal and sagittal angles for the tibia, were the methods used for anatomical graft placement. In 2015, T. Vermersch et al. [21] did a study on CT assessment of femoral tunnel placement and found 124 femoral tunnels (68.9 %) were in the optimal position and 56 (31.1 %) were not. A radiologic evaluation of the femoral and tibial tunnel placement based on anatomic landmarks in arthroscopic single-bundle anterior cruciate ligament restoration was conducted in 2017 by S.K. Nema et al. [22]. M.R. Patel et al. [23] conducted a study on the tibial tunnel position of 39 patients using the above parameters and concluded that a CT scan is an imaging modality to study tunnel position after ACL reconstruction.

In our study, we used the Lysholm scoring system functional outcome evaluation. The scores improved from 80.91 at three months to 89.23 at 12 months in the anatomical group, while in the non-anatomical group, they remained the same (58.58) even at 12 months' follow-up. Of 30 patients from the anatomical group, 28 patients showed either excellent or good scores and only two patients had fair and poor scores. This is statistically significant. W. Wang et al. [24] in their study showed that the Lysholm scoring questionnaire is reliable, valid, and responsible for the evaluation of patients with ACL injuries and it would be an effective evaluation tool. D. Mashreghi et al. [25] used the Lysholm scoring system for the functional evaluation of ACL reconstruction in 140 operated cases with the hamstring graft.

In our study only two patients had swelling and one patient had a stiff knee which was managed with physiotherapy. One patient developed infection that was managed with antibiotics.

CONCLUSION

This study concludes that the functional outcome after arthroscopic anterior cruciate ligament reconstruction is better when the graft is placed in an anatomical footprint of native ACL for both femoral and tibial tunnels. Also, the functional scores in the anatomical group of patients improved after the surgery and at follow-ups.

Conflict of interest *There is no conflicts of interest.*

Funding *None.*

Ethics approval and consent to participate *The study was approval by the institutional review board (IRB).*

Consent for publication *Consent was taken from all the participants.*

Availability of data and materials *The datasets used in and/or analyzed in the current study are available from the corresponding author upon reasonable request.*

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The article was submitted 26.02.2025; approved after reviewing 21.04.2025; accepted for publication 25.08.2025.

Статья поступила 26.02.2025; одобрена после рецензирования 21.04.2025; принята к публикации 25.08.2025.

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