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Trends in Revision ACL Reconstruction: Analysis of 257 Procedures

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Background. Despite the anterior cruciate ligament reconstruction (ACL-R) is considered to be routine and successful procedure the burden of patients who needs revision surgery is growing worldwide.
Purpose — to describe the gender and social-demographic characteristics of this cohort of patients, analyze the reasons leading to revision ACL-R (re-ACL-R), estimate survival-ship of primary procedure as well as highlight clinically relative aspects of revision surgery.
Methods. The database of Vreden Orthopaedic Center for the period from 01.01.2011 to 31.12.2021 searched for patients admitted for re-ACL-R. 234 patients (257 knees) agreed to take part in the study. Patient records with surgery reports, clinical exams and PROM's were analyzed.
Results. There was a tendency to annual increase of re-ACL-R while the time between primary and revision procedures was just 4.0 years in average. Young males dominated among re-ACL-R cohort (75.2%, 31.0 years). The acute trauma prevailed over other reasons of ACL-R failure however, it was absent in 39.1% of cases. Patients who injured performing sports were significantly younger than the rest of the cohort ($p = 0.005$). Allografts were the most popular choice both for first re-ACL-R (53.0%) and re-revision ACL-R (60.9%). Interestingly that majority of re-ACL-R were performed in one stage while two-staged approach implemented only in 4.3% of cases.
Conclusion. The main cause for re-ACL-R is repeated injury but significant percentage of patients develops recurrence of instability without trauma in middle-term period after ACL-R. Therefore to reduce the numbers of re-ACL-R both the proper post-op sport injury prevention program and improvement of surgical technique are of the same importance.

Keywords: knee, anterior cruciate ligament reconstruction, revision surgery, knee arthroscopy.

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Структура операций ревизионной пластики передней крестообразной связки: анализ 257 наблюдений

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Введение. В настоящее время на фоне широкого распространения реконструкции передней крестообразной связки (ПКС), несмотря на довольно высокие показатели успешных исходов, возрастает потребность в ревизионных реконструкциях, которые более сложны, чем первичные вмешательства.
Цель исследования — изучить структуру операций ревизионной реконструкции передней крестообразной связки, определить роль повторной травмы в причинах несостоятельности первичного трансплантата, объем вмешательств, а также сроки с момента выполнения предшествующей операции.
Материал и методы. Проведен ретро- и проспективный анализ 257 ревизионных реконструкций ПКС у 234 пациентов, выполненных в НМИЦ ТО им. Р.Р. Вредена с 2011 по 2021 г. Исследование включало оценку половозрастного состава пациентов, причин выполненных ревизий, объема и особенностей вмешательств, а также сроков с момента выполнения предшествующей реконструкции ПКС.
Результаты. Отмечена тенденция к ежегодному росту количества выполняемых ревизионных реконструкций ПКС, причем медиана срока выполнения ревизии составляет всего 4,0 года. Среди пациентов, которым выполнялась ревизионная реконструкция ПКС, преобладали мужчины (75,2%), а медиана возраста составила 31,0 год (25,0–36,0 лет). Среди причин ревизионной пластики ПКС на первом месте была повторная травма, однако в 38,9% наблюдений она отсутствовала. Пациенты, получившие повторную травму во время занятий спортом, были достоверно моложе остальной когорты (p = 0,005). Наиболее популярными при ревизионной реконструкции ПКС были трансплантаты аллогенного происхождения: они использовались в 53,0% случаях первичных ревизий и в 60,9% повторных ревизий. Большинство ревизионных реконструкций ПКС (95,7%) выполнялось одноэтапно, и только в 4,3% случаев применялся двухэтапный подход.
Заключение. Несмотря на то, что основными причинами ревизионных реконструкций ПКС явились повторные травмы, существенная доля пациентов нуждалась в данном вмешательстве без повторного повреждения, что обусловлено погрешностями выполнения первичного вмешательства. Таким образом, для снижения тренда к увеличению подобных операций необходимо создание системы профилактики повторных травм у прооперированных пациентов, а также совершенствование технологий первичного вмешательства.

Ключевые слова: коленный сустав, передняя крестообразная связка, реконструкция, ревизия, артроскопия.

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BACKGROUND

Anterior cruciate ligament (ACL) injuries are one of the most common knee injuries, especially among young patients [1]. Specifically, up to 200,000 cases of ACL rupture are registered annually in the USA alone [2]. With persistent pain and various symptoms of instability, surgical treatment is indicated to restore knee function and allow the patient to return to his/her habitual level of physical activity and sports. In this regard, ACL reconstruction is now widely used.

Although ACL reconstruction is a successful orthopedic surgery that enables achieving a high rate of positive outcomes, the proportion of poor outcomes with graft failure can reach 17% [3]. As the total number of primary ACL reconstructions increases, the need for revision surgeries also increases. In major multicenter cohort studies, ACL revision rates range from 1.7% to 7.7% [4, 5]. Moreover, approximately 13,000 revision interventions on the ACL are performed annually in the USA alone [6].

The increased interest in this problem in the scientific community, which can be assessed by the dynamics of publication activity, is also noteworthy. The first single report on various aspects of ACL revision in the PubMed dates back to the early 1980s (Fig. 1). However, from 2000 to the present, the number of publications increased exponentially, reaching 191 in 2021.

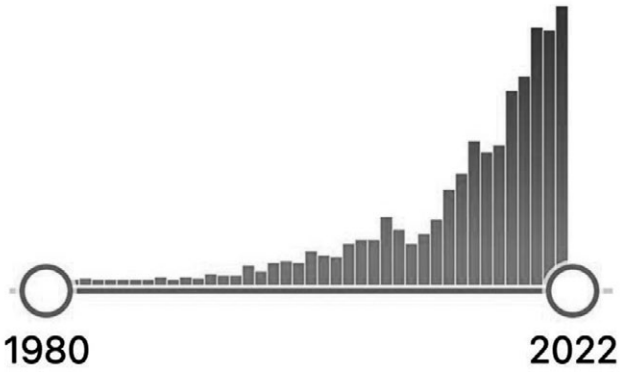

Fig. 1. Dynamics of publication activity in the PubMed database upon request 'revision ACL reconstruction'

Thus, in recent decades, interest in ACL revision reconstruction has increased significantly in the presence of an increasing need for such interventions in clinical practice. Clinical experience gained in Vreden Russian Center of Traumatology and Orthopedics enabled analysis of ACL revision reconstructions using large data and highlighted the most relevant aspects.

This study aimed to analyze the structure of revision reconstructions of the ACL and consider the role of repeated trauma in the occurrence of primary graft failure, scope of interventions, and time elapsed since the previous intervention.

METHODS

Data were obtained retrospectively and prospectively from the general base of surgeries of the Vreden Russian Center of Traumatology and Orthopedics on 234 patients, including 176 men (75.2%) and 58 women (24.8%), who underwent ACL revision grafting from 2011 to 2021. The median age of the patients during the intervention was 31.0 (25.0–36.0) years. These patients underwent 257 surgical interventions in total, including 234 primary interventions and 23 repeated (re-revisions) revisions of the ACL. The retrospective part of the study included 164 cases, whereas the prospective part included 70 cases.

We analyzed the number of variables, namely, dynamics of the number of revision surgeries over the study period, presence and nature of injuries after primary ACL reconstruction, types of grafts used, and frequency of their use during primary and repeated ACL reconstructions.

Statistical analysis

Accumulation, correction, and systematization of initial information and visualization of the results obtained were performed in Microsoft Office Excel (2020). Statistical analysis was performed using the StatTech v. 2.5.9 software (Stattech, Russia). Quantitative indicators were assessed for compliance with the normal distribution using the Shapiro-Wilk test (<50 participants) or the Kolmogorov-Smirnov test (>50 participants). In the absence of a normal distribution, quantitative data were described using the median (Me) and lower and upper quartiles (Q1-Q3).

Categorical data were described with absolute values and percentages. Comparison of three or more groups in terms of a quantitative indicator, which distribution differed from the normal one, was performed using the Kruskal-Wallis test, and a

posteriori comparisons were performed using the Dunn test with Holm's correction. Percentages in the analysis of multifield contingency tables were compared using Pearson's χ^2 test.

RESULTS

The number of ACL revision reconstructions performed at the Vreden Russian Scientific Center of Traumatology and Orthopedics from 2011 to 2021, constantly increased (except for 2019 and 2020), which reached 43 in 2021 (Fig. 2).

Regarding the timing of revision surgery for the primary reconstruction of the ACL, more than half of the revisions (57.1%) were performed during the first 5 years (Fig. 3). The median period for revision interventions was only 4.0 (3.0–8.0) years.

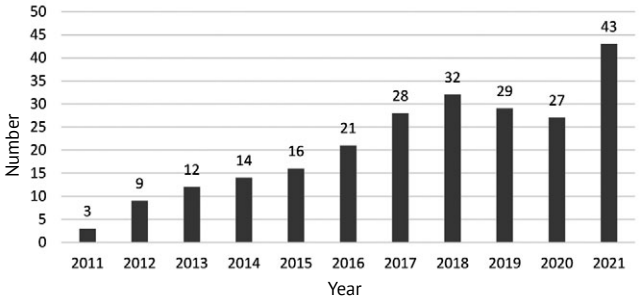

Fig. 2. Dynamics of revision ACL reconstructions at Vreden Orthopedic Center

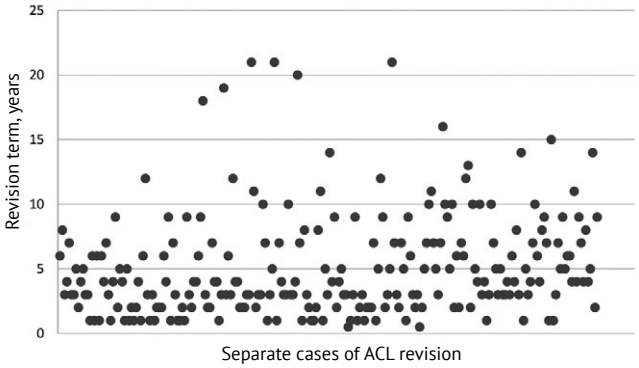

Fig. 3. Terms of revision ACL reconstruction from the primary (previous), years

As regards the dependence of the time elapsed between the surgeries on the type of primary graft, significant differences were revealed ($p = 0.013$) (Table 1). Thus, the highest median revision term was registered in patients with synthetic prosthesis and autotendon graft from the middle third of the patellar ligament with bone blocks (bone-patellar tendon-bone [BTB]), followed by allografts and autografts from the tendon of the semitendinosus and gracilis (STG) muscles.

Repeated injuries, which necessitate ACL revision reconstruction, were registered in 143 (61.1%) patients. Moreover, injuries received at home prevailed over sports injuries (79 – 33.8%) and 64 (27.4%), respectively). The proportion of patients without a history of injury before ACL revision reconstruction was smaller, and their number was nevertheless quite large (91 (38.9%) patients).

In our comparison of re-injury rate with the type of primary graft ($p = 0.366$) and patient's sex ($p = 0.281$), significant relationship was not found. However, when determining the dependence of re-injury and its type on the patient's age, significant differences were noted ($p = 0.005$). Thus, patients with sports-related re-injuries were younger than the others (Table 2).

We analyzed the types of grafts used and the frequency of their use in patients during primary and repeated ACL reconstructions. Accordingly, the types of grafts used during primary and revision surgeries were comparable; however, the frequency of their use varied significantly. Thus, autologous tendons of the STG muscles, middle third of the patellar ligament with BTB, quadriceps tendon (QT), and peroneus longus (PL); allografts of the long peroneal, posterior tibial muscles, and ligaments of the patella; and synthetic prostheses were used as grafts for ACL replacement. During ACL revision and re-revision, surgeons more often than others preferred allotendinous grafts, compared with autotendons of the STG muscles during primary reconstruction (Table 3).

Table 1

Period of time between surgeries depending on the primary graft type

Graft type	Period between surgeries, years		n	p*
	Me	Q1–Q3		
Auto STG	3.6	2.2–5.7	138	$p_{auto\ BTB—auto\ STG} = 0.026$ $p_{allo—auto\ STG} = 0.421$ $p_{synthetic—auto\ STG} = 0.031$ $p_{allo—auto\ BTB} = 0.138$ $p_{synthetic—auto\ BTB} = 0.967$ $p_{synthetic—allo} = 0.218$ $p_{tot.} = 0.013$
Auto BTB	6.0	2.8–8.4	35	
Allo	4.2	2.4–6.9	41	
Synthetic prosthesis	6.4	2.5–12.1	20	

STG — tendon of the semitendinous and gracilis muscles; BTB — middle third of the patellar ligament with bone blocks; Allo — allotendinous graft; * differences in indicators are significant ptot. = 0.013 (<0.05).

Table 2

Dependence of repeated injuries on age

Re-injury	Age, years		n	p*
	Me	$Q_1–Q_3$		
None	33.0	25.0–38.0	91	$p_{sports-related—none} = 0.011$ $p_{home—none} = 0.931$ $p_{home—sports-related} = 0.020$ $p_{tot.} = 0.005$*
Sports-related	28.0	24.0–34.0	64	
Home	31.0	26.0–37.0	79	

Differences in indicators are significant $p_{tot.} = 0.005$ (<0.05).

Table 3

Types of grafts used, *n* (%)

Graft type	Primary reconstruction of the ACL	ACL revision	ACL re-revision
Auto STG	138 (59.0)	33 (14.1)	1 (4.3)
Auto BTB	35 (15.0)	70 (29.9)	8 (34.8)
Allo TP	26 (11.1)	88 (37.6)	9 (39.1)
Allo PL	15 (6.4)	35 (15.0)	3 (13.1)
Allo BTB	0 (0.0)	1 (0.4)	2 (8.7)
Synthetic prosthesis	20 (8.5)	3 (1.3)	0 (0.0)
Auto QT	0 (0.0)	1 (0.4)	0 (0.0)
Auto PL	0 (0.0)	2(0.9)	0 (0.0)
Contralateral auto STG	0 (0.0)	1 (0.4)	0 (0.0)
Total	234 (100)	234 (100)	23 (100)

STG — tendon of the semitendinous and gracilis muscles; BTB — middle third of the patellar ligament with bone blocks; QT — quadriceps tendon; PL — peroneus longus tendon; TP — posterior tibial tendon; Allo — allotendinous graft.

Among the allografts, the tendon of the posterior tibial muscle was preferred. All allografts were prepared by the Department of Organ and Tissue Conservation of the Vreden Russian Center of Traumatology and Orthopedics. An antiseptic complex in a frost-resistant liquid medium was used to sterilize tissues. This method has certain advantages over others such as gamma irradiation, gaseous ethylene oxide, diluted solutions of formalin with antibiotics, and hydrogen peroxide. The main advantages of sterilization using an antiseptic complex in a frost-resistant liquid medium are the ease of storage, convenient transportation of grafts, and minimal influence on the material structure and biological properties [7].

In this study, 203 (86.8%) patients underwent isolated revision reconstruction of the ACL, and only 31 (13.2%) required combined surgery with additional grafting of other stabilizers of the knee joint, namely, posterior crucial ligament, medial and lateral collateral ligaments, etc.

Mostly, surgeons resorted to the one-stage revision technique, whereas the two-stage technique was performed in only 10 (4.3%) cases. A two-stage revision reconstruction of the ACL was performed if bone grafting of the canals was required (5 (2.1%)), after sanitizing surgeries because of complications such as surgical infection (3 (1.3%)), or arthrolysis in the case of severe arthrofibrosis of the knee joint, which was performed as stage 1 before ACL revision remodeling (2 (0.9%)).

Bone grafting during ACL revision was necessary in only 12 (5%) cases. In addition to bone grafting at stage 1 of treatment, it was also performed simultaneously with ACL revision in 7 (2.9%) cases. Spongious allogenic bone grafts (n = 9) were used more often than autologous (from the iliac crest) bone grafts (n = 3). A bone defect (2.5%, n = 6) in the femoral canal required plastic replacement slightly less frequently than a tibial defect (4.2%, n = 10).

DISCUSSION

In this study, the key aspects established were the characteristics of demographic indicators, assessment of the role of repeated trauma in graft failure and revision reconstruction of the ACL, and change over time in the number of such interventions and clinical features of their implementation, including the frequency of use of various grafts.

First, our data on the age and sex distribution of patients who underwent ACL revision reconstruction are comparable with the global scientific literature, as the majority of patients are young people, mostly men [8]. This can be due to the high prevalence of sports-related knee joint injuries with ACL rupture, requiring its reconstruction, in this population. This predetermines possible revision surgery at various terms after primary surgery.

Second, the materials analyzed enabled the evaluation of the effect of repeated trauma on ACL graft failure and damage. Generally, the reasons for the revision reconstruction of the ACL are quite diverse, and they are usually grouped into larger categories. Specifically, it is proposed to consider separately traumatic and atraumatic causes of ACL revision reconstruction. Category 1 includes patients who sustained repeated trauma in various conditions (at home and/or sports-related), after which instability recurrence was noted following graft damage and/or failure [9]. The proportion of patients in whom recurrent instability and subsequent ACL revision remodeling occurred after re-injury was 61.1%. According to scientific studies, this indicator ranges from 18% to 79% [10, 11]. Category 2 includes patients in whom an unsatisfactory result (persistent instability, pain, and limited knee joint range of motion) is not associated with repeated episodes of injury and manifests at different times after the primary surgical intervention. In this study, 38.9% of the cases were included in this category, and technical errors are the most common cause of complications. These include incorrect positioning of the channels, graft, and undiagnosed combined injuries of other stabilizers of the knee joint [12, 13]. Among atraumatic causes, rehabilitation failure, biological factors, and infectious complications are less often registered [14]. In this study, we did not aim to provide details of atraumatic causes of ACL graft failure.

Third, in the vast majority of the cases (95.7%) analyzed in this study, surgeons resorted to a one-stage ACL revision technique. This approach eliminates the risks of repeated surgery and anesthesia, reduces the period of persistent instability in the knee joint and the time for complete

recovery, and has economic advantages [15]. Nevertheless, a one-stage revision of the ACL is not always indicated and technically possible. The most common reason for a two-stage revision of the ACL is the need for plastic replacement of extensive bone defects in the area of existing canals [16]. In addition, such an approach is appropriate in cases of surgical infection and arthrofibrosis. Data from the Multicenter Revision ACL Reconstruction Study (MARS) show that two-stage revision reconstruction is performed in 8–9% of cases [17].

Fourth, during revision surgery, a rather wide variability in the use of various grafts remains; however, allotendinous materials prevailed, which account for 52.6% during primary revisions and 60.9% during re-revisions, which is comparable with publications by other authors. Thus, according to MARS, 54% of the surgeons preferred allografts, whereas 27% preferred primary grafting [17]. The problem of choosing the optimal graft remains for both primary and revision ACL reconstructions. In the scientific community, this aspect is still actively discussed; however, there is no clear answer to the question of which transplant is preferable [18, 19]. The high popularity of allografts can be explained by the limited choice of autografts and technical aspects of the ACL revision reconstruction. Allografts, due to their varying sizes and conditionally unlimited number, are quite convenient for ACL revision grafting, especially when multi-ligament reconstruction and filling of limited bone defects are required [20]. In this study, multi-ligamentary reconstructions account for only 13% of all ACL revision surgeries.

Thus, the annual increase in the number of revision reconstructions of the ACL and the short periods when it becomes necessary to perform repeated surgeries require the creation of a system of measures aimed at preventing repeated injuries in operated patients, not only during sports activities, but also in everyday life, and the improvement of primary intervention technologies. Considering that different methods of primary and revision reconstruction of the ACL is currently used in clinical practice, including various approaches to the formation of channels, types of grafts, and methods of their fixation, the national registry of ACL grafting could become the best tool for studying modifiable risk factors for repeated surgeries. International analogs of ACL registers have been successfully functioning over the past years in several countries [21, 22]. The creation and implementation of such a register of ACL reconstruction in Russia could increase the amount of clinical materials available for analysis from various medical institutions, which is necessary for a qualitative increase in the clinical and scientific value of further research in this field.

CONCLUSION

Among patients undergoing ACL revision grafting, men predominate significantly (>75%). In most cases, repeated trauma is the reason necessitating revision reconstruction of the ACL. However, the proportion of patients requiring this intervention without a history of re-injury remains very high (38.9%), which is most often due to primary surgery failure. In the vast majority of cases, surgeons resort to one-stage revision reconstruction of the ACL, which has advantages in cases where its implementation is technically possible and does not worsen the outcomes. Allogeneic tendon and tendon-bone grafts are popular because they facilitate the technical solution of the tasks that the surgeon faces during ACL revision reconstruction.

DISCLAIMERS

Author contribution

Saprykin A.S. — the concept and design of study, data collection, analysis and interpretation of the obtained data, statistical data processing, writing of the manuscript.

Rybinin M.V. — the concept and design of the study, writing and editing of the manuscript.

Kornilov N.N. — the concept and design of the study, writing and editing of the manuscript, interpretation the obtained data.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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Competing interests. The authors declare that they have no competing interests.

Ethics approval. Not applicable.

Consent for publication. Not required.

REFERENCES

1. Acevedo R.J., Rivera-Vega A., Miranda G., Micheo W. Anterior cruciate ligament injury: identification of risk factors and prevention strategies. *Curr Sports Med Rep.* 2014;13(3):186-191. doi: 10.1249/JSR.0000000000000053.
2. Frobell R.B., Roos E.M., Roos H.P., Ranstam J., Lohmander L.S. A randomized trial of treatment for acute anterior cruciate ligament tears. *N Engl J Med.* 2010;363(4):331-342. doi: 10.1056/NEJMoa0907797.
3. Sanders T.L., Pareek A., Hewett T.E., Levy B.A., Dahm D.L., Stuart M.J. et al. Long-term rate of graft failure after ACL reconstruction: a geographic population cohort analysis. *Knee Surg Sports Traumatol Arthrosc.* 2017;25(1):222-228. doi: 10.1007/s00167-016-4275-y.
4. Hettrich C.M., Dunn W.R., Reinke E.K., Spindler K.P.; MOON Group; Spindler K.P. The rate of subsequent surgery and predictors after anterior cruciate ligament reconstruction: two- and 6-year follow-up results from a multicenter cohort. *Am J Sports Med.* 2013;41(7):534-40. doi: 10.1177/0363546513490277.
5. Leiter J.R., Gourlay R., McRae S., de Korompay N., MacDonald P.B. Long-term follow-up of ACL reconstruction with hamstring autograft. *Knee Surg Sports Traumatol Arthrosc.* 2014;22(5):1061-1069. doi: 10.1007/s00167-013-2466-3.
6. Leroux T., Wasserstein D., Dwyer T., Ogilvie-Harris D.J., Marks P.H., Bach B.R. Jr. et al. The epidemiology of revision anterior cruciate ligament reconstruction in Ontario, Canada. *Am J Sports Med.* 2014;42(11): 2666-2672. doi: 10.1177/0363546514548165.
7. Rykov Y.A. [Comparative assessment of morphologic evolution of tendinous and bone allografts sterilized using different methods]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2010;(1):172-174. (In Russian). doi: 10.21823/2311-2905-2010-0-1-172-174.
8. Dini F., Tecame A., Ampollini A., Adravanti P. Multiple ACL Revision: Failure Analysis and Clinical Outcomes. *J Knee Surg*. 2021;34(8):801-809.
9. Samitier G., Marcano A.I., Alentorn-Geli E., Cugat R., Farmer K.W., Moser M.W. Failure of Anterior Cruciate Ligament Reconstruction. *Arch Bone Jt Surg.* 2015;3(4):220-240.
10. Grassi A., Kim C., Marcheggiani Muccioli G.M., Zaffagnini S., Amendola A. What Is the Mid-term Failure Rate of Revision ACL Reconstruction? A Systematic Review. *Clin Orthop Relat Res*. 2017;475(10):2484-2499. doi: 10.1007/s11999-017-5379-5.
11. Yan X., Yang X.G., Feng J.T., Liu B., Hu Y.C. Does Revision Anterior Cruciate Ligament (ACL) Reconstruction Provide Similar Clinical Outcomes to Primary ACL Reconstruction? A Systematic Review and Meta-Analysis *Orthop Surg*. 2020;12(6):1534-1546. doi: 10.1111/os.12638.
12. Desai N., Andernord D., Sundemo D., Alentorn-Geli E., Musahl V., Fu F. et al. Revision surgery in anterior cruciate ligament reconstruction: a cohort study of 17,682 patients from the Swedish National Knee Ligament Register. *Knee Surg Sports Traumatol Arthrosc.* 2017;25(5):1542-1554. doi: 10.1007/s00167-016-4399-0.
13. Bantser S.A., Trachuk A.P., Bogopol'sky O.E., Tikhilov R.M., Sushkov I.V., Murga E.A. [Effect of bone tunnels positioning on outcomes of transtibial anterior cruciate ligament reconstruction]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2017;23(3):7-16. doi : 10.21823/2311-2905-2017-23-3-7-16.
14. Wylie J.D., Marchand L.S., Burks R.T. Etiologic Factors That Lead to Failure After Primary Anterior Cruciate Ligament Surgery. *Clin Sports Med*. 2017;36(1):155-172.
15. Richter D.L., Werner B.C., Miller M.D. Surgical Pearls in Revision Anterior Cruciate Ligament Surgery: When Must I Stage? *Clin Sports Med.* 2017;36(1):173-187. doi: 10.1016/j.csm.2016.08.008.
16. de Sa D., Crum R..J, Rabuck S., Ayeni O., Bedi A., Baraga M. et al. The REVision Using Imaging to Guide Staging and Evaluation (REVISE) in ACL Reconstruction Classification. *J Knee Surg.* 2021;34(5):509-519. doi: 10.1055/s-0039-1697902.
17. MARS Group, Wright R.W., Huston L.J., Spindler K.P., Dunn W.R., Haas A.K. et al. Descriptive epidemiology of the Multicenter ACL Revision Study (MARS) cohort. *Am J Sports Med.* 2010;38(10):1979-1986. doi: 10.1177/0363546510378645.
18. Duchman K.R., Lynch T.S., Spindler K.P. Graft Selection in Anterior Cruciate Ligament Surgery: Who gets What and Why? *Clin Sports Med.* 2017;36(1):25-33. doi: 10.1016/j.csm.2016.08.013.
19. Mall N.A., Abrams G.D., Azar F.M., Traina S.M., Allen A.A., Parker R. et al. Trends in primary and revision anterior cruciate ligament reconstruction among National Basketball Association team physicians. *Am J Orthop (Belle Mead NJ)*. 2014;43(6):267-271.
20. Condello V., Zdanowicz U., Di Matteo B., Spalding T., Gelber P.E., Adravanti P. et al. Allograft tendons are a safe and effective option for revision ACL reconstruction: a clinical review. *Knee Surg Sports Traumatol Arthrosc.* 2019;27(6):1771-1781. doi: 10.1007/s00167-018-5147-4.
21. Kvist J., Kartus J., Karlsson J., Forssblad M. Results from the Swedish national anterior cruciate ligament register. *Arthroscopy*. 2014;30(7):803-810. doi: 10.1016/j.arthro.2014.02.036.22.
22. Snaebjörnsson T., Hamrin Senorski E., Svantesson E., Westin O., Persson A., Karlsson J. et al. Graft Fixation and Timing of Surgery Are Predictors of Early Anterior Cruciate Ligament Revision: A Cohort Study from the Swedish and Norwegian Knee Ligament Registries Based on 18,425 Patients. *JB JS Open Access.* 2019;4(4):e0037. doi: 10.2106/JBJS.OA.19.00037.

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