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# Одноэтапная ревизионная реконструкция передней крестообразной связки с использованием аутотрансплантата: ретроспективное когортное исследование

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***АННОТАЦИЯ***

***Обоснование.*** Ревизионная реконструкция передней крестообразной связки (ПКС) является технически более сложной манипуляцией, чем первичная. Рецидив передней нестабильности чаще всего связан с технической ошибкой во время выполнения первичной операции. Первоочередной задачей ревизионной реконструкции служит обнаружение причины рецидива передней нестабильности и тщательное предоперационное планирование. Крайне важно использовать принципы анатомического расположения ПКС для восстановления стабильности. В статье рассматриваются варианты ревизионной анатомической реконструкции ПКС, включая хирургическую технику, предоперационную подготовку, выбор материала для аутотрансплантата.

***Цель.*** Оценить результаты одноэтапной ревизионной реконструкции ПКС и показать, что этот вид вмешательства можно выполнить в 1, а не в 2 этапа, что приведёт к сокращению сроков восстановления пациента и его возвращения к своим привычным физическим нагрузкам.

***Материалы и методы.*** Для наблюдения отдалённых результатов лечения мы выбрали 50 из 92 пациентов с ревизионной одноэтапной реконструкцией ПКС, которые прошли обследование через 9 и 12 мес после операции. Все пациенты были молодого работоспособного возраста от 18 до 42 лет (средний возраст 29,2 года). В группу вошли пациенты только мужского пола. С целью получения материала для трансплантата всем пациентам выполняли взятие сухожилий тонкой и полусухожильной мышцы с больной или контрлатеральной конечности. Для оценки результатов лечения были использованы шкала IKDC, Лисхольма, артрометрическое тестирование на KT-1000 и функциональные тесты.

***Результаты.*** Применение разработанных хирургических подходов позволило получить хорошие результаты лечения пациентов с рецидивами передней нестабильности по шкале Lysholm (82 балла). В наблюдаемой группе остаточную латеральную нестабильность II степени наблюдали у 2 (4%) пациентов, в контрольной группе — у 7 (14%) больных. По шкале субъективной оценки результатов лечения исходами лечения остались удовлетворены 19 (38%) человек.

***Заключение.*** Практическое применение предложенных вариантов расположения каналов и способы фиксации аутотрансплантата во внутрикостных каналах позволяют выполнить ревизионную артроскопическую реконструкцию ПКС в 1 этап, без применения дополнительной костной пластики каналов, что, в свою очередь, сокращает сроки лечения и восстановления пациентов, о чём свидетельствуют полученные нами результаты.

**Ключевые слова:** ревизионная реконструкция передней крестообразной связки; разрыв передней крестообразной связки; рецидив передней нестабильности.

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ЭКО•ВЕКТОР

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# One-stage revision reconstruction of the anterior cruciate ligament using autograft: retrospective cohort study

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***ABSTRACT***

***BACKGROUND:*** Revision reconstruction of the anterior cruciate ligament (ACL) is a technically more complex procedure than primary reconstruction. Recurrence of anterior instability is most often associated with a technical error during the primary operation. The primary task of revision reconstruction is to identify the cause of recurrence of anterior instability and careful preoperative planning. Thus, the principles of ACL anatomical location to be essential restore stability. This paper discusses options for revision anatomical reconstruction of the ACL, including surgical technique, preoperative preparation, and choice of autograft material.

***AIM:*** This study aimed to evaluate the results of a one-stage revision reconstruction of the ACL and show that this method can be performed in one stage, rather than in two stages, which will lead to a reduction in the patient's recovery time and return to usual physical activity.

***MATERIALS AND METHODS:*** To monitor the long-term treatment results, 50 of 92 patients with revision through one-stage ACL reconstruction, who were examined 9, and 12 months after surgery, were enrolled. All patients were young, who were working from age 18 to 42 years. The mean age was 29 years. This group included only male patients. As a graft material, all patients underwent sampling of the tendons of the fine and semitendinous muscles from the diseased or the contralateral limb. To assess the treatment results, the IKDC scale, Lysholm scale, arthrometric testing on KT-1000, and functional tests were conducted.

***RESULTS:*** The use of developed surgical approaches made it possible to obtain good treatment results in patients with recurrences of anterior instability according to the Lysholm score of 82 points. Grade II residual lateral instability was observed in two (4%) patients in the observed group and in seven (14%) patients in the control group. According to the subjective assessment of treatment outcomes, 19 patients (38%) remained satisfied with them.

***CONCLUSION:*** The practical application of the proposed options for the location of the channels and methods for fixing the autograft in the intraosseous channels make it possible to perform revision arthroscopic reconstruction of the ACL in one stage, without additional bone grafting of the channels, which in turn reduces the treatment and recovery time of patients, as evidenced by the results.

**Keywords:** revision reconstruction of the anterior cruciate ligament; anterior cruciate ligament rupture; recurrence of anterior instability.

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ECO•VECTOR

# BACKGROUND

An anterior cruciate ligament (ACL) reconstruction of the knee joint is becoming an increasingly common orthopedic surgery. In Russia, >5,000 ACL reconstruction surgeries are performed annually. Successful surgical interventions account for 75%–90% of cases in the most famous medical centers in the country. Despite the use of contemporary technologies and techniques for ACL reconstruction, the rate of poor treatment results remains high. According to the literature, the proportion of poor results ranges from 10.5% to 45%.

Surgical treatment of recurrent instability after primary ACL reconstruction remains an unresolved problem. In contrast to primary reconstruction, revision of knee ACL reconstruction is often the surgery of choice with very limited goals. This limitation is not accidental. Similar to primary reconstruction, revision surgery aims to select the appropriate graft material and implant it in the isometric region of the tibia and femur. In most cases, surgeons resort to a two-stage revision of ACL reconstruction; when stage 1 is plastic surgery of previously formed intraosseous channels, and after the channels are closed, on average after 1 year, stage 2 is ACL reconstruction [1, 2].

Early recurrence of anterior knee joint instability is primarily associated with improper surgical technique, functional graft failure, preterm return to sports, and inappropriate rehabilitation [3]. A recurrence in the late postoperative period, occurring more than a year after ACL reconstruction, is usually associated with a new onset of trauma or recurrent graft macrotraumatization [4, 5]. The literature reveals that 60% of reconstruction revision cases are associated with a "technical error," in which inappropriate topical location of the femoral channel is the most common [6]. Several anatomical landmarks have been described, which determine the ACL attachment to the tibia, including the anterior tibial spine, posterior border of the anterior horn of the lateral meniscus, and posterior cruciate ligament (PCL). The femoral attachment of the ACL is located on the posteromedial surface of the lateral condyle of the femur within the intercondylar fossa. Primarily, the ACL limits the tibial displacement anteriorly relative to the femur. However, its secondary role includes resistance to the rotation of the tibia and varus and valgus loads on the knee joint.

Instability recurrence can also occur without obvious graft rupture, which is associated with its incorrect topical location. The vertical location of the femoral channel can lead to persistent rotational instability of the knee joint, which limits the athlete's ability to return to the previous load level [2]. A very anterior positioning of the femoral channel and a very posterior positioning of the tibial channel result in flexion loss, while anterior positioning of the tibial channel leads to graft impingement and extension loss [7].

**This study aimed** to evaluate the results of a one-stage revision of ACL reconstruction and demonstrate that this surgery can be performed in one instead of two stages, which helps reduce the patient's recovery time and return to habitual physical activity.

# MATERIALS AND METHODS

## Study design

A retrospective cohort study was conducted. The results were evaluated at three visits: before the surgery and 9 and 12 months after the surgery.

## Study conditions

For the period from 2020 to April 2021, 92 patients were recorded to experience recurrence of knee joint instability after ACL reconstruction in the department of sports and ballet trauma of the N.N. Priorov National Medical Research Center of Traumatology and Orthopedics (Moscow). In 88 (95.7%) patients, primary surgeries were performed in other medical institutions in the country, and 4 (4.3%) patients underwent surgery in our clinic.

The following causes were established as causes of instability recurrence:

- Inappropriate topical location of intraosseous channels in the femur and tibia (*n*=67, 73%)
- Repeated traumas of the knee joint (*n*=18, 19%)
- Errors in patient management during the rehabilitation period (*n*=7.8%).

## Eligibility criteria

*The inclusion criteria were as follows:*

- Recurrence of instability due to damage or failure of the ACL autograft
- Availability of radiation diagnostic data (magnetic resonance imaging (MRI), and computed tomography (CT))
- Signed voluntary informed consent to participate in the study

*The exclusion criteria were as follows:*

- Failure to visit for any of the control examinations (9 or 12 months after the surgery or both visits)
- Lack of data from radiological studies (MRI) and failure of diagnostic tests.

## Description of medical intervention

*Stage 1 of the surgery* included an arthroscopic revision of the joint cavity to confirm graft failure or rupture and identify damage to other structures of the knee joint and assess the condition of the articular cartilage. After examining the joint cavity, the previous auto- or allograft was removed; the condition of the intraosseous channels and intercondylar fossa was assessed; and if necessary, plastic surgery was performed. The location of the channels relative to the anatomical site of the native ACL attachment can be divided into the following three categories:

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- Non-anatomical, where the channels are completely outside the anatomical site of attachment of the native ACL
- Anatomical, where the channels are completely inside the anatomical site of attachment
- Semi-anatomical, where the channels cover partially the anatomical site of ACL attachment [8].

Most often, we found a non-anatomical location of the channels, which did not cause difficulties in the formation of a new intraosseous channel.

In this study, 1 (1.1%) patient had a chronic infection of the knee joint (gonitis), which led to autograft lysis, cartilage destruction, and fibrin deposition. The autograft remnants and fixing structures were removed, and the joint cavity with drains through the intraosseous channels of the femur and tibia was drained. Then, a constant inflow–outflow system was used for washing the joint cavity for 7 days. This patient did not undergo repeated ACL plastic surgeries because he did not notice the knee joint instability in the late postoperative period, which was most probably due to the scar formation in the knee joint cavity.

During the knee joint cavity revision, the meniscus and cartilage were also assessed. In all cases, we identified either degenerative changes in the menisci or their damage, usually in the white zone, requiring partial meniscectomy. During preoperative planning, articular cartilage changes were usually more pronounced than expected according to radiographs and MRI results. Articular cartilage changes were determined by depth, size, and position using the Waterbridge classification. The cartilage was treated with a high-frequency ablator and shaver (debridement). Detection of a cartilage defect up to the subchondral bone was not a contraindication for revision surgery. Such lesions were treated by tunneling or microfracturing.

The intercondylar fossa was usually filled with scar tissue, which also included remnants of an ACL autograft or allograft. Autograft removal was quite easy and efficient, whereas allograft (dacron) removal was more time-consuming because of the rough structure of the material.

If a screw in the femur must be removed, the bone and soft tissue around the screw were cleaned completely before its removal. Screws from the tibial and femoral channels were not removed in 14 (15.2%) patients (10 femoral, 4 tibial) because they did not interfere with the surgery. In 5 (5.4%) cases, the primary tibial channel was used because its location corresponded to the correct one. The fixing structures were removed, and the sclerotic walls of the channel were drilled with a drill corresponding to the channel diameter, till the clean bone.

*Stage 2 of surgical treatment* included tendon harvesting for grafting and ACL plastic surgery. In most cases, tendon harvesting was performed from the contralateral limb; however, in 10 (10.9%) patients, it was performed from the affected limb because allografts or the patellar ligament with bone blocks were used for primary plastic surgery.

*The actual revision surgery* was similar to the primary ACL plastic surgery, and achieving the correct anatomical location of the channels was the focus. Since the landmarks were less clear than that in primary plastic surgery, the PCL attachment site was a landmark for the tibial channel location, and the new channel was tried to be placed in the middle and slightly medial to the intercondylar eminence. When the primary intraosseous channel was located outwardly in the tibia, we formed inwardly a new channel of a larger diameter and centered the graft in the channel using a BioIntrafix sleeve (DePuy Mitek, USA) (Fig. 1).

When the primary channel was displaced inwards, the graft was removed, a screw was inserted there, and a new channel with a diameter of 6–7 mm was formed. The screw was inserted to not break the wall of the new channel (Fig. 2).

If the primary channel was located anteriorly or posteriorly (Fig. 3), a standard channel in the tibial bone was performed. When making a channel of a larger diameter, the graft was centered in the channel using Milagro screws (DePuy Mitek, USA).

During the revision of ACL reconstruction, in 1 (1.1%) case, the location of the tibial channel was near the anterior horn of the internal meniscus (Figs. 4, 5).

When forming the femoral channel, we focused on the posterior wall of the intercondylar fossa. In most cases, no problems were encountered during site selection for the formation of a new femoral channel. When the primary femoral channel was located anteriorly, a new channel was formed 2–3 mm posteriorly and no more than 7 mm in diameter (Fig. 6).

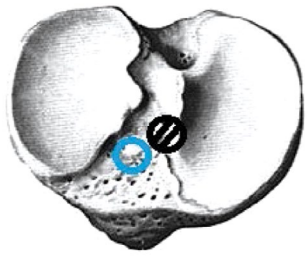

**Fig. 1.** The location of the primary tibial canal outward, ○ — correct channel placement.

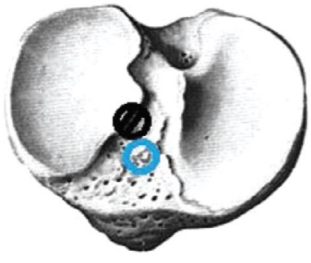

**Fig. 2.** The location of the tibial canal inside, ○ — correct channel placement.

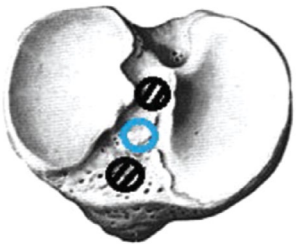

**Fig. 3.** Variants of the location of the tibial canals, ○ — correct channel placement.

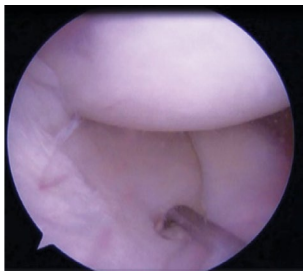

**Fig. 4.** Location of the tibial canal near the anterior horn of the meniscus.

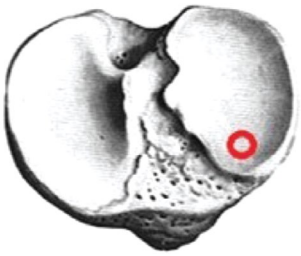

**Fig. 5.** Channel layout.

**Fig. 6.** Anterior location of the femoral canal, ○ — correct channel placement.

If the femoral channel was located posteriorly, the new channel was displaced anteriorly, and a 6–7 mm-thick graft was used (Fig. 7).

In some cases, the femoral channel was located high, so we make a standard intraosseous channel corresponding to the diameter of the resulting autograft (Figs. 8–10). At a low location, a new femoral channel was formed more proximal, and the channel was also centered on the tibia medially by 2 mm (Fig. 11).

In addition to the inappropriate topical location of the channels in the femoral condyle in 6 (6.5%) patients, another problem occurred, i.e., the channel had a large (>12 mm) diameter. In such cases, fixators (Milagro) were additionally used to center the autograft in the channel from 2–3 sides (Fig. 12). Control examination of the patients was performed 3, 6, and 12 months after the surgery.

## Research outcomes

*The main outcome of the study* was the restoration of limb functionality (questionnaire and clinical test). *Additional outcomes* were the preservation of the ACL autograft on MRI.

## Methods of outcome registration

The preoperative examination included X-ray images of the knee joint in two views, namely, anteroposterior and lateral in full lower leg extension in the knee joint. Before the surgery, CT of the knee joint was obligatory. CT images were used to determine the topical location of the femoral

**Fig. 7.** Posterior position of the femoral canal, ○ — correct channel placement.

**Fig. 8.** High position of the femoral canal, ○ — correct channel placement.

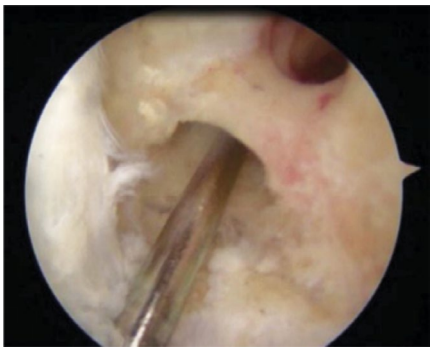

**Fig. 9.** New intraosseous canal in the femur, malformed canal above.

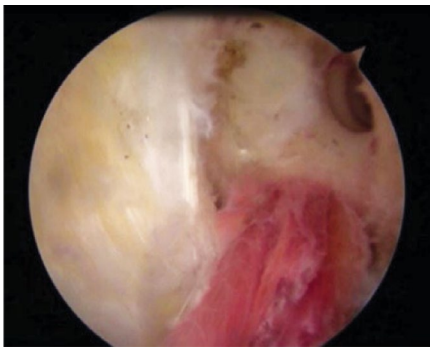

**Fig. 10.** Final view after autograft.

**Fig. 11.** Low position of the femoral canal, ○ — correct channel placement.

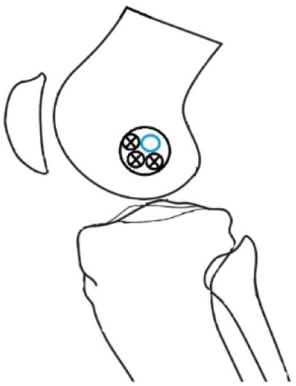

**Fig. 12.** Canal diameter more than 12 mm, graft centering using 2–3 screws.

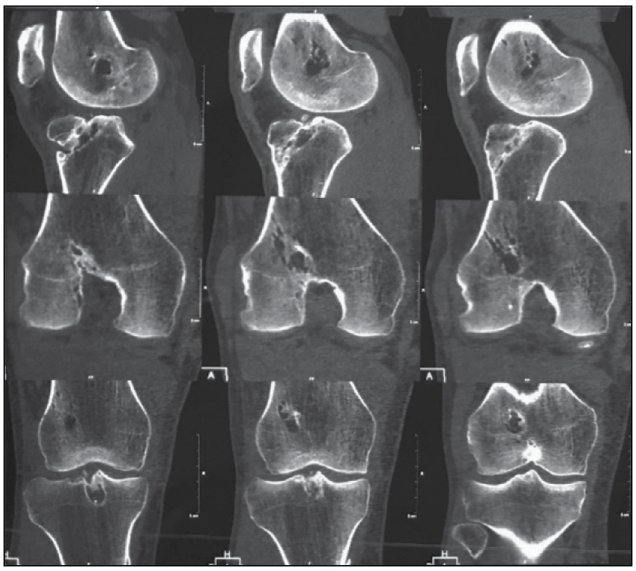

**Fig. 13.** Preoperative CT-scans.

and tibial channels, their enlargement, narrowing of the joint cavity, and location and type of the fixing structure (Fig. 13).

Patients' medical records were evaluated to determine the size of the intraosseous channels and type of the fixation structures. The correction was made by comparing the diameter measured with CT and the true diameter of the intraosseous channel. In all cases, CT revealed an increase in the diameter of the intraosseous channels and a violation of their topical location.

An MRI of the knee joint was also performed, which provided additional information regarding damage to the ACL autograft and other intra-articular structures of the knee joint (meniscus, PCL, lateral ligaments, and intra-articular cartilage), especially in the case of repeated injuries. In all cases, a thorough clinical examination was performed, including the Lachman and pivot shift tests. Further examinations were also performed under anesthesia immediately before surgery for a timely diagnosis of complex instability of the knee joint. To assess the treatment results, the IKDC 2000 and Lysholm scales and instrumental methods using a KT-1000 arthrometer (MEDmetric Corp., USA) were employed.

## Ethical considerations

The study was performed in accordance with the requirements of the Declaration of Helsinki (1973). It was approved by the Local Ethics Committee of the N.N. Priorov National Medical Research Center of Traumatology and Orthopedics (Minutes No. 5/21 dated May 21, 2021).

## Statistical analysis

The sample size was determined by the department capacity for the indicated years of the study. The sample size was not preliminarily calculated. SPSS Statistics v. 15.0 (SPSS Inc., Chicago, IL, USA) was used for statistical data processing. Numerical data, indicating the research results, are presented as $M \pm m$, where $M$ is the mean value and $m$ is

the standard deviation. For ordinal variables, the frequencies of values and proportions (%) relative to the number of valid cases and a comparison of quantitative and qualitative signs in the studied groups are provided. Nonparametric statistical methods were used for the analysis. The nonparametric Mann–Whitney *U*-test was used to assess differences between the compared mean values of the studied parameters in the groups. The threshold level of statistical significance ($p$) was set at $p < 0.05$.

# RESULTS

## Study participants

To follow up long-term treatment results, 50 patients with revision of ACL reconstruction were selected, and they were examined 3, 6, 9, and 12 months after surgery. All patients were of working age, ranging from 18 to 42 (mean age, 29.2) years. The study group included only male patients. The tendons of the gracilis and semitendinosus muscles from the affected or contralateral extremity were used as the graft material in all patients. The graft was fixed on the femur and tibia using the Ridfix system and BIO-INTRAFIX Tibial system, respectively. In some cases, Milagro screws were also used to ensure reliable fixation of the autograft during revision surgery.

## Main study results

Treatment outcomes were evaluated 3–12 months after surgery in 50 (54%) of 92 patients. The results were assessed on the Lysholm scale, where a good result was a score of >77 points; satisfactory, 67–77 points; and poor, ≤66 points according to the IKDS 2000 protocol (determining movement amplitude and performing tests to determine instability). Good treatment results were registered in 39 (78%) patients (mean 78 points), satisfactory results were noted in 10 (20%) patients (69 points), and poor results were registered in 1 (2%) patient (65 points). The mean IKDS score before surgery was 23.42, and when evaluating long-term treatment results, it was 87.21.

In the examination using the KT-1000 arthrometer before surgery, the average displacement of the lower leg was approximately 11 mm, and it was 2.5 mm 12 months after the surgery.

The intensity of the pain syndrome was assessed using a 10-point visual analog scale (VAS), and severe pain sensations (>5) were recorded in 72% of patients before surgery. The mean VAS score before surgery was 7.5. In the long-term follow-up period, 2 (4%) patients with severe deforming arthrosis had pain syndrome with a score of >4.0. The mean VAS score after surgery was 2.0 points. After the surgery, all patients showed an improvement in subjective and objective conditions.

Most of the respondents (85%) were satisfied with the treatment results. Patients return to the previous level of professional activity after 6–10 months.

The one-stage revision of ACL reconstruction has remarkably reduced the treatment time for patients. Only 1 (2%) patient could not return to the previous level of professional activity because of the progression of the knee joint osteoarthritis, and this patient underwent knee arthroplasty 2 years later.

# DISCUSSION

## Summary of the main research outcome

The two-stage treatment for revision of ACL repair is technically more complex than one-stage repair, and the treatment results are potentially worse, especially for active patients who impose high demands on their physical activity level. With careful preoperative preparation, the probability of a one-stage ACL revision increases substantially, which can considerably reduce the treatment time and material costs.

## Discussion of the main research results

ACL reconstruction enables the correction of anterior knee joint instability caused by ACL rupture and has become very popular over the past two decades. Graft failure can occur because of technical, biological, and mechanical factors. Errors in the surgical technique, such as the non-anatomical location of the intraosseous channels, are the most common cause of unsuccessful ACL reconstruction, which was confirmed in 73% of our patients.

Careful preoperative planning of ACL reconstruction revision is a very important component of a successful intervention. When planning ACL reconstruction revision, it is necessary to study thoroughly the patient's medical history, conduct a complete physical and instrumental examination, decide on the choice of graft material, select preliminarily the surgical technique, and develop a rehabilitation plan. The professional activity of the patient must be considered as well. The patient's expectations are often not consistent with reality; therefore, despite the achievement of knee joint stability, revision surgery does not satisfy the patient's desire. Instability and/or pain are the main patient complaints. Thus, before the intervention, the doctor should explain to the patient that reduced activity and good muscle tone in the thighs and lower legs can decrease the severity or even eliminate instability symptoms even without surgery. ACL revision should be offered to patients who cannot cope with instability or who want to increase their physical activity level. Patients should be warned about the risk of gradual progression of osteoarthritis, regardless of the treatment method, and explained that pain most probably results from the degenerative processes in the cartilage and that repeated ACL repair will not solve the problem. This information should be an important part of the patient consultation before ACL revision. In our study, one of the patients had not recovered the previous level of physical activity because of persistent knee joint pain.

The most common error in the surgery technique is the location of the femoral or tibial channel anteriorly. In

patients who undergo surgical treatment repeatedly, this problem became the most common cause of unsuccessful primary ACL reconstruction (28% tibial and 72% femoral). A posterior and proximal location of the femoral channel is preferable and results in minimal stretching of the ACL autograft. A more anterior and distal location of the femoral channel along the arch of the fossa causes graft stretching during flexion and induces recurrence. The correct position of the tibial channel is also very important for a good result. The tibial channel location in the anterior intercondylar field causes its impingement during lower leg extension in the knee joint (impingement syndrome), which leads to gradual loosening and graft failure.

For ACL reconstruction revision, the graft material and fixation type are also very important. The doctor must be familiar with the most common surgical techniques. The issue of what is better to use for revision plastic surgery, auto- or allograft, has been discussed for a long time [9]. Although the use of an allograft alleviated pain at the harvesting site, other problems include engraftment to the bone and body response to foreign material, which is manifested by synovitis of the knee joint. The degree of elastic resistance and coefficient of elasticity in allografts are much higher, which subsequently leads to a more rapid progression of deforming arthrosis than the use of autografts. An allograft should be used only if it is impossible to collect autologous material or if the patient refuses it. Noyes et al. published the results of ACL reconstruction revision using a cadaveric fresh-frozen allograft, where unsuccessful surgeries accounted for 33% of cases over 42 months of follow-up. These patients used fresh-frozen allografts sterilized with γ-irradiation at a dose of 25,000 Gy [10, 11]. Although the authors believe that the change in the mechanical properties of the graft under the influence of γ-radiation and deep freezing was within acceptable limits, this assumption was not proven and could explain the relatively high rate of instability recurrence. Noyes et al. suggested that an allograft should not be used in revision surgery. In the absence of automaterials available for harvesting, the authors recommend using allograft augmentation using a portion of the iliotibial tract to reduce the rate of instability recurrence [11].

Fox et al. recently published the results of ACL reconstruction revision using a non-irradiated patellar tendon allograft [12]. They assessed treatment outcomes in 32 (84%) of 38 patients. The mean age of the patients was 28 years, and the mean follow-up period was 4.8 years. Postoperative CT-1000 arthrometry showed that in 10% of the patients, anterior displacement of the lower leg was >5 mm, which indicates an unsuccessful surgery, although the instability recurrence rate was substantially lower than with an irradiated allograft.

After ACL reconstruction, due to lysis, the intraosseous channels enlarged. Although the outcome of this phenomenon is not yet fully understood, dilation of the intraosseous channels can be of great importance in revision surgery, as it complicates the choice of the location of the new channel and graft fixation. Many assumptions have been put forward regarding the causes of this complication. In our opinion, as the most appropriate point of view, the cause of lysis has a multifactorial origin. Mechanical and biological causes were believed to contribute to tunnel dilation. In the analyzed group, the channels (femoral and tibial) dilated in all patients who underwent ACL reconstruction revision. In 7 (14%) patients, where the channels were ⩾12 mm (5 femoral and 2 tibial channels), and to overcome this situation, in addition to the standard graft fixation, we used 2 or 3 Milagro screws for additional fixation and filled the cavity of enlarged intraosseous channels. In 14 (28%) patients, we did not remove the fixation structures to avoid weakening bone structure during the formation of a topically correctly located new channel, and they did not interfere with the surgical course.

At the very start of the postoperative period, fixation is the weakest part of any ACL reconstruction (primary or revision). In all cases, we used the same fixation as in the primary ACL reconstruction.

The rehabilitation program in patients with reconstruction revision was the same as in primary reconstruction because we did not reveal any remarkable differences in the objective and subjective assessments of instability in patients with primary and revision of ACL reconstruction.

Our results were remarkably better than those reported in the literature regarding the measurement of instability and recurrence rate. In 1 (2%) patient, graft malfunction was noted after 12 months, and the patient complained of instability. During arthroscopic revision in this patient, we discovered complete lysis of the autograft. As a result, poor results accounted for 2.5% in our study. In another patient, the anterior displacement of the lower leg when measured on the KT-1000 arthrometer was 5 mm, which suggests joint instability. However, this patient did not complain of instability because it was compensated by the good tone of the thigh muscles; thus, repeated surgical interventions were not required.

### Study limitations

This study is limited by its retrospective nature. In the future, we plan to conduct a prospective comparative study with a preliminary calculation of the sample size to comply with the principles of evidence-based medicine.

## CONCLUSION

ACL reconstruction revision is a complex procedure that includes a more thorough clinical examination, radiographic evaluation, and preoperative testing, as opposed to primary reconstruction. Difficulties with reconstruction revision include new channel formation, channel dilation due to lysis, associated trauma, and choice of graft material. Surgical

success is ensured by minimal surgical errors and the choice of the most appropriate ACL reconstruction technique. The proposed options for the location of the channels and methods for autograft fixing in the intraosseous channels help in the arthroscopic revision of ACL reconstruction in one stage, without the use of additional bone grafting of the channels, which reduces the treatment time and promotes recovery of the patients.

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## СПИСОК ЛИТЕРАТУРЫ

**1.** Brown C.H. Jr., Carson E.W. Revision anterior cruciate ligament surgery // Clin Sports Med. 1999. Vol. 18, N 1. P. 109–171. doi: 10.1016/s0278-5919(05)70133-2

**2.** Wilde J., Bedi A., Altchek D.W. Revision Anterior Cruciate Ligament Reconstruction // Sports Health. 2014. Vol. 6, N 6. P. 504–518. doi: 10.1177/1941738113500910

**3.** George M.S., Dunn W.R., Spindler K.P. Current concepts review: revision anterior cruciate ligament reconstruction // Am J Sports Med. 2006. Vol. 34, N 12. P. 2026–2037. doi: 10.1177/0363546506295026

**4.** Harner C.D., Giffin J.R., Dunteman R.C., et al. Evaluation and treatment of recurrent instability after anterior cruciate ligament reconstruction // Instr Course Lect. 2001. N 50. P. 463–474.

**5.** Johnson D.L., Fu F.H. Anterior cruciate ligament reconstruction: why do failures occur? // Instr Course Lect. 1995. N 44. P. 391–406.

**6.** Morgan J.A., Dahm D., Levy B., et al. Femoral tunnel malposition in ACL revision reconstruction // J Knee Surg. 2012. Vol. 25, N 5. P. 361–368. doi: 10.1055/s-0031-1299662

**7.** Kamath G.V., Redfern J.C., Greis P.E., Burks R.T. Revision anterior cruciate ligament reconstruction // Am J Sports Med. 2011. Vol. 39, N 1. P. 199–217. doi: 10.1177/0363546510370929

**8.** Hofbauer M., Murawski C.D., Muller B., et al. Revision surgery after primary double-bundle ACL reconstruction: AAOS exhibit selection // J Bone Joint Surg Am. 2014. Vol. 96, N 4. P. e30. doi: 10.2106/JBJS.M.01038

**9.** Engelman G.H., Carry P.M., Hitt K.G., et al. Comparison of allograft versus autograft anterior cruciate ligament reconstruction graft survival in an active adolescent cohort // Am J Sports Med. 2014. Vol. 42, N 10. P. 2311–2318. doi: 10.1177/0363546514541935

**10.** Noyes F.R., Barber-Westin S.D. Anterior Cruciate Ligament Graft Placement Recommendations and Bone-Patellar Tendon-Bone Graft Indications to Restore Knee Stability // Instr Course Lect. 2011. N 60. P. 499–521.

**11.** Noyes F.R., Barber-Westin S.D. Revision anterior cruciate ligament reconstruction: report of 11-year experience and results in 114 consecutive patients // Instr Course Lect. 2001. N 50. P. 451–461.

**12.** Fox, J. A., Pierce, M., Bojchuk, J., et al. Revision anterior cruciate ligament reconstruction with nonirradiated fresh-frozen patellar tendon allograft // Arthroscopy. 2004. Vol 20. N 8. P. 787–794. doi: 10.1016/j.arthro.2004.07.019

## REFERENCES

**1.** Brown CH Jr, Carson EW. Revision anterior cruciate ligament surgery. *Clin Sports Med*. 1999;18(1):109–171. doi: 10.1016/s0278-5919(05)70133-2

**2.** Wilde J, Bedi A, Altchek DW. Revision Anterior Cruciate Ligament Reconstruction. *Sports Health*. 2014;6(6):504–518. doi: 10.1177/1941738113500910

**3.** George MS, Dunn WR, Spindler KP. Current concepts review: revision anterior cruciate ligament reconstruction. *Am J Sports Med*. 2006;34(12):2026–2037. doi: 10.1177/0363546506295026

**4.** Harner CD, Giffin JR, Dunteman RC, et al. Evaluation and treatment of recurrent instability after anterior cruciate ligament reconstruction. *Instr Course Lect*. 2001;50:463–474.

**5.** Johnson DL, Fu FH. Anterior cruciate ligament reconstruction: why do failures occur? *Instr Course Lect*. 1995;44:391–406.

**6.** Morgan JA, Dahm D, Levy B, et al. Femoral tunnel malposition in ACL revision reconstruction. *J Knee Surg*. 2012;25(5):361–368. doi: 10.1055/s-0031-1299662

**7.** Kamath GV, Redfern JC, Greis PE, Burks RT. Revision anterior cruciate ligament reconstruction. *Am J Sports Med*. 2011;39(1):199–217. doi: 10.1177/0363546510370929

**8.** Hofbauer M, Murawski CD, Muller B, et al. Revision surgery after primary double-bundle ACL reconstruction: AAOS exhibit selection. *J Bone Joint Surg Am*. 2014;96(4):e30. doi: 10.2106/JBJS.M.01038

**9.** Engelman GH, Carry PM, Hitt KG, et al. Comparison of allograft versus autograft anterior cruciate ligament reconstruction graft survival in an active adolescent cohort. *Am J Sports Med*. 2014;42(10):2311–2318. doi: 10.1177/0363546514541935

**10.** Noyes FR, Barber-Westin SD. Anterior Cruciate Ligament Graft Placement Recommendations and Bone-Patellar Tendon-Bone Graft Indications to Restore Knee Stability. *Instr Course Lect*. 2011;60:499–521.

**11.** Noyes FR, Barber-Westin SD. Revision anterior cruciate ligament reconstruction: report of 11-year experience and results in 114 consecutive patients. *Instr Course Lect*. 2001;50:451–461.

**12.** Fox JA, Pierce M, Bojchuk J, et al. Revision anterior cruciate ligament reconstruction with nonirradiated fresh-frozen patellar tendon allograft. *Arthroscopy*. 2004;20(8):787–794. doi: 10.1016/j.arthro.2004.07.019

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