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ARTHROSCOPIC RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT OF THE KNEE JOINT. CHOOSING THE OPTIMAL GRAFT

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ABSTRACT

Over the past three decades, there have been revolutionary changes in the concepts of knee joint pathology and methods of its correction. The most frequent and significant functional and prognostic pathology of the knee joint for young and middle-aged people is a rupture of the anterior cruciate ligament, which occurs on average in every third of patients with a sports injury of this segment. Advances in the diagnosis and treatment of anterior cruciate ligament injuries are associated with further deepening of subspecialization in traumatology and orthopedics. The article reflects the latest trends in domestic and world orthopedic arthrology. Today's operations for the reconstruction of the anterior cruciate ligament are technically complex and constantly improving surgical interventions. In addition to the dominance of the endoscopic approach in the diagnosis and organ-preserving treatment of various types of knee joint pathology, it is characterized by the complexity of reconstructive and reconstructive interventions. The narrow specialization in traumatology has accelerated the development and implementation of new approaches, methods, tools, and materials. The purpose of this article is to eliminate the gap in the issues of modern diagnosis and treatment in people with anterior cruciate ligament of the knee joint with an emphasis on real opportunities to work in medical institutions.

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Introduction

The knee joint (KJ) in the human musculoskeletal system is the largest, most complex, and most easily vulnerable. It is formed by three bone structures: the distal end of the femur, the proximal end of the tibia, and the patella. Also, two large joints are formed in it – the femoral-tibial and femoral-patellar [1]. The cruciate ligaments are located inside the joint but are separated from its cavity by the synovial membrane. They consist of many fibers combined into two main bundles. From the modern positions of knee joint biomechanics, cruciate and collateral ligaments are more appropriate to consider no longer as isolated monolithic structures, but as ligamentous complexes with a complex structure and their biomechanics in the context of the knee joint [2].

Rupture of the anterior cruciate ligament (ACL) is one of the most common knee joint injuries, especially in people of working age, somatically healthy and lead an active lifestyle [3]. In the USA, up to 200 thousand cases of such an injury are registered annually [3]. In this regard, arthroscopic ACL reconstruction is a common orthopedic operation that allows patients to restore

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the function of the knee joint and return to a fully active lifestyle. Thus, according to foreign national registers, the number of such interventions annually amounts to 32 cases per 100 thousand people in Sweden, and 52 cases per 100 thousand people in Australia. At the same time, there is a constant absolute increase in ACL reconstructions performed annually [4, 5].
The main function of the ACL in knee joint biomechanics is to prevent anterior subluxation of both condyles and rotational subluxation of the outer condyle of the tibia in its most vulnerable positions (150 – 170°). Signs of damage to the ligamentous apparatus KJ in the acute period are manifested as a sharp pain in the knee joint area, limited mobility, reflex muscle tension, effusion into the joint cavity, swelling of the periarticular tissues, and hemarthrosis [6]. Diagnosis of ACL damage is based on the identification of its anatomical defect and a typical functional deficiency of the patient's knee joint. Modern functional diagnostics of the knee joint allow, during manual testing, to simulate a pathological anterolateral rotational subluxation of the tibia, characterizing pathognomonic functional failure [7].
There are several options for detecting anterolateral rotational instability, such as the "pivot shift" phenomenon, the "front drawer" symptom, and the Lachman test. When receiving evidence of complete functional failure of the ACL during manual testing, it is possible to diagnose its anatomical damage. The introduction of magnetic resonance imaging (MRI), computed tomography (CT), and arthroscopy into wide clinical practice have significantly expanded the possibilities of an objective assessment of the pathological anatomy of the knee joint, qualitatively improving its diagnosis. It is generally recognized that the most informative method of additional diagnosis of intraarticular KJ damage is MRI. A distinctive feature of MRI is the possibility of detailed visualization of both bone and all soft tissue structures of KJ.
The high frequency of unsatisfactory results after ACL reconstruction is because the surgeon faces several tasks that need to be performed for the full recovery of this category of patients. At the same time, in the modern scientific environment, some aspects of surgical treatment of patients with knee instability, such as the choice of optimal surgical tactics and techniques, as well as the type of transplant, remain controversial. In this review, based on the analysis of current literature, we studied the most clinically significant features of the diagnosis and reconstruction of the ACL of the knee joint.
The purpose of the study: based on the analysis of current literature, to study and highlight the most clinically significant features of ACL reconstruction and the choice of the optimal graft.

Materials and Methods

We conducted a search for English- and Russian-language publications in the electronic databases MEDLINE (National Medical Library), PubMed, and eLibrary for the period from 2013 to 2023 using the keywords: knee joint (KJ), anterior cruciate ligament (ACL), instability, autoplasty, diagnostics.
Among 594 papers, 183 publications corresponded to the context of the study. Of these, according to the inclusion criteria (more than 64 cases in the report; follow-up period of more than 2 years; homogeneous groups of patients; assessment of knee joint function using arthrometry and special scales (Lysholm score, Tegner activity score, International Knee Documentation Committee); application of various imaging options of the knee joint (MRI, CT, and radiography), 20 messages were selected for analysis. Among them, 10 randomized controlled trials (RCTs) were selected.
As a result of the search, no Russian works matching the above criteria were found.
In addition, all bibliographies of relevant publications have been checked for further study.

Results and Discussion

The analysis made it possible to identify the most clinically significant elements in the treatment of patients in need of ACL reconstruction:

- criteria for choosing the ACL reconstruction technique;
- additional features of ACL reconstruction;
- selection of the optimal graft type;

The key point in planning the tactics and method of ACL reconstruction is a preoperative examination of the patient to assess the damage to the ACL, whether the injury was primary or relapse associated with the functional failure of the ACL graft.
To date, plastic surgery of the anterior cruciate ligament is the most frequently performed typical high-tech reconstructive organ-preserving surgery not only on the knee joint but also on the human musculoskeletal system as a whole. According to modern generally recognized international standards, it is performed according to the endoscopic technique. Thanks to well-developed technology, it has now become available to almost every orthopedic traumatologist specializing in knee surgery.
The basic principles of modern ACL reconstructions are minimal invasiveness, anatomicity, isometricity, and functional stability of the graft. Minimal invasiveness implies the preservation of a stable part of the distal ligament stump as a source of reparative regeneration, incorporation, and reconstruction of the graft, as well as a sparing attitude to intra-articular structures and, above all, hyaline cartilage of the condyles.

Indications for Primary Reconstruction of the Anterior Cruciate Ligament of the Knee Joint

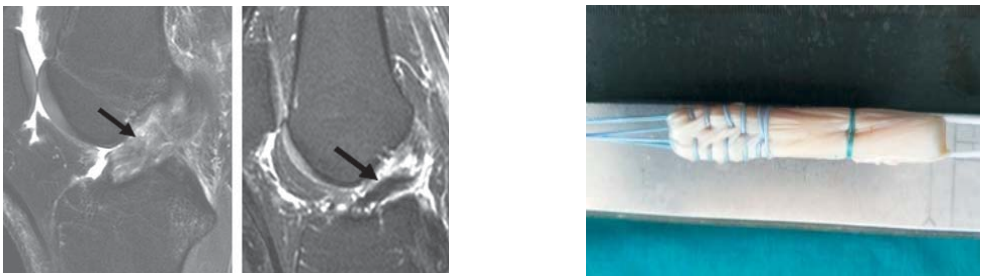
a. Acute/subacute rupture of the anterior cruciate ligament
b. ACL insufficiency with clinically significant instability of the knee joint (the knee turns up or "flies out")

c. Physically active/physiologically young patient
d. Clinically significant instability /subluxation of the knee joint
e. The patient's ability and desire to follow the requirements of the postoperative rehabilitation program
f. Errors in the choice of indications:
   - Map-predictable / suboptimal result of surgery in conditions of pronounced degenerative knee joint damage
   - Multiple ligament instability (including posterior-external angle and posterior cruciate ligament)
   - Fresh dislocation of the patella, clinically resembling ACL injury
   - Rupture of the meniscus of the "watering can handle" type with dislocation can form a "terminal pseudococcus" during the Lachman test, as well as mechanically prevent full extension of the knee joint
   - It is advisable to postpone the operation until the synovitis is relieved, the volume of movements is normalized (especially the restoration of full extension) and the function of the quadriceps is restored [8].

High-tech MRI of the knee joint is by far the simplest, most accessible, and at the same time informative method of examining the knee joint, which is primarily resorted to by most patients who have suffered an injury to it.
In the MRI image, an ACL rupture is assumed where the ligament is completely absent in its usual place, has a broken contour of the bundles, or is depicted as a wavy or arcuate line **(Figure 1a)**.

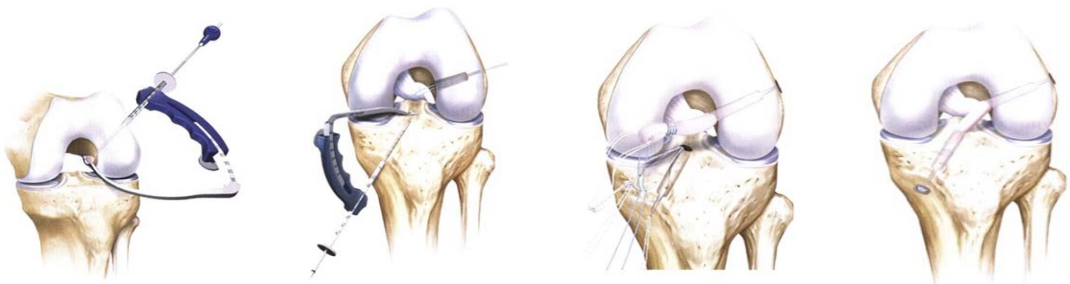
The Technique of the Operation of the Standard Reconstruction of the Anterior Cruciate Ligament According to the All-Inside "All-Inside" Technique
Stage 1: diagnostic arthroscopy of the knee joint and preparation for ACL reconstruction
Stage 2: Graft collection. As an autotransplant, the quadrilateral tendon of the semi-tendon muscle is most often used (the diameter of a cylindrical four-bundle monograft in cross-section averages 8-10 mm **(Figure 1b)**.
Stage 3: formation of channels in the thigh and tibia:
a. a retrograde reamer is inserted through the outer condyle of the femur into the center of the femoral footprint of the ACL **(Figure 2a)**.
b. The tibial landing socket is formed similarly with the help of a tibial guide and the same retrograde reamer **(Figure 2b)**.

Stage 4: carrying out and fixing the graft:
a. The graft is inserted into the joint cavity with the use of conductor threads. First, the proximal end of the graft is completely immersed into the femoral canal **(Figure 2c)**, then its distal end is carried into the tibial canal
b. Suspending fixation devices fix the threads passed through the ends of the graft on the surface of the thigh and tibia, after which the necessary tension of the graft is performed with simultaneous flexion and extension of the knee joint **(Figure 2d)** [9].



a) b)

Figure 1. The technique of the operation: a) MRI of the knee joint with acute (left) and long-standing (right) ACL ruptures. b) The appearance of a four-bundle monograft from a tendon of a semi-tendon muscle for single-bundle ACL reconstruction



a) b) c) d)

Figure 2. All-inside technique

From the point of view of durability, terms of incorporation, and restructuring, autografts have an absolute priority **(Figure 3)**. Allografts taken from donors, due to the foreignness of the tissue subjected to sterilization and preservation, are less favorable for use as a plastic material and are acceptable for use only in cases of a lack of autologous (own) material during repeated revision and multi-ligation reconstructions in people with low physical and athletic activity. They undergo biological restructuring for a longer period, have an increased risk of rupture in the postoperative period, and should not be considered the main plastic material in military personnel, professional athletes, and physically active young patients [10].

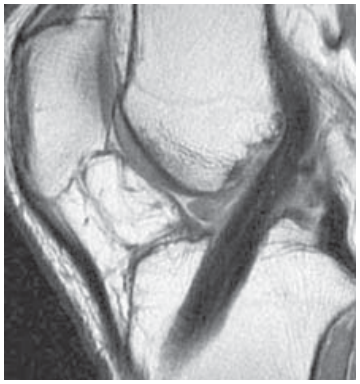


Figure 3. An MRI picture of the knee joint in the sagittal plane shows a reconstructed ACL autograft.

Biomechanical characteristics of transplants:

a. The biomechanical characteristics of transplants are influenced by factors such as the size of the graft, the technique of its preparation, the age of the donor, and the method of fixation:
   - Average tear load in the native anterior cruciate ligament → 2160N
   - Fourfold folded autosuchons of semi-tendon and tender muscles → 4590N
   - Autograft from patellar tendon with bone plugs → 2977N
   - Autosuction of the quadriceps muscle → 2352N

b. Chemically treated or sterilized by irradiation allografts have less strength than allografts subjected to deep freezing and not exposed to chemicals and ionizing radiation:
   - Freezing only destroys the cells without affecting the strength characteristics of the transplants

c. Reconstructions using allografts should not be used in young patients: the risk of ACL failure when using allografts in such patients increases fourfold.

d. Types of transplants **(Table 1)**:
   - BTB-autograft (one of the gold standards)
   - Autosuction of the semi-tendon muscle (ST) (another gold standard)
   - Autosuction of the quadriceps muscle (with or without a bone plug from the patella)
   - Allosuchons: BTB, ST, Achilles tendon, Anterior/posterior tibial muscle, quadriceps.

Table 1. Differentiation of graft selection in ACL plastic surgery

Graft type	Advantages	Disadvantages	Other
Auto-BTB	Fast integration with the bone bed; Possibility of rigid fixation in the joint; A good choice for patients with high functional requirements or patients with systemic joint hypermobility; Higher stability in laboratory conditions compared to ST-grafts	Increased risk of developing pain in the anterior part of the knee joint; Risk of patellar fracture; Risk of patellar tendon rupture; Risk of damage to the subclavian branch of the subcutaneous nerve.	Contraindications: Diseases of the femoral-patellar joint; Patellar tendon tendinitis; Immaturity of the bone system; The active phase of Osgood-Schlatter disease; There may be a discrepancy between the size of the graft and the bone channels due to the excessive length of the tendon
Auto-ST	Lower risk of pain syndrome in the anterior part of the knee joint and no risk of patellar fracture; Less extended access and less pronounced postoperative pain syndrome; A four-fold graft from a tendon of a semi-tendon muscle has a maximum tensile strength	Higher risk of infectious complications compared to BTB or alloplasty; A slight decrease in the flexion force of the knee joint, especially at maximum bending angles; Slightly reduced graft fixation strength	Slightly increased frequency of expansion of the boundaries of bone channels; There may be a functionally significant weakness of the posterior thigh muscle group in female athletes

Autosuction of the quadriceps muscle	No problem of mismatch between the size of the graft and bone channels; The ability to form a stronger graft with a larger diameter; Lower risk of pain syndrome in the anterior part of the knee joint or sensitive disorders compared to BTB	There may be problems with the elimination of a defect in the quadriceps tendon after graft removal, problems with wound healing, and extravasation of fluid from the knee joint cavity through a tendon defect; Depending on the size of the patient and the technique of sampling, there may be problems with choosing the appropriate length of the graft	The graft is often harvested with a bone plug from the upper pole of the patella; In the studies available today concerning the strength characteristics of this graft, rather contradictory information is provided; When sampling, it is better to form a full-layer graft
Allografts	No problems in the place of graft collection; A choice of larger diameter grafts is possible; Reduction of operation time; Faster rehabilitation is possible	Increase in the cost of the operation; Significant increase in the risk of graft failure in young patients (<25 years); There may be problems with graft integration; Risk of infection with hemotransmissive infections	It may be the method of choice for some revision interventions or multiple knee ligament injuries; Exposure to ionizing radiation or chemicals on the graft reduces its strength and can lead to osteolysis

BTB – bone-tendon-bone; ST - semitendinosus

The fascination in recent years with tendon grafts (ST – "semitendinosus tendon" - tendon of the semi–tendon muscle, or HT - "hamstring tendons" - hamstrings) did not lead to the rejection of its use, but only more clearly defined the indications, taking place mainly in revision reconstructions or in cases where it is impossible to use these soft-tissue tendons. Even though the main objection to the use of BTB grafts is considered to be a pain in the area of the donor site on the anterior surface of the knee joint, the main reason for the most frequent use is the technical simplicity and shortening of the duration of operations with the use of HT grafts. However, the relatively high frequency of relapses and residual instability after the use of HT grafts increasingly leads to the idea of the expediency of returning to the "gold standard" of BTB and during primary reconstructions in young and physically active patients belonging to the "high-risk group".
The use of BTB grafts is carried out according to the general concept of ACL reconstruction. The differences are only in the technique of sampling, preparation, and fixation of the graft.

Conclusion

1. Restoration of knee joint function after arthroscopic ACL reconstruction takes more than 6 months and depends on the plastic material used: BTB is characterized by regressive insufficiency of the quadriceps femoris and patellar crepitation in 64.3% of cases, for STG – slower recovery of activity of the flexor muscles of the lower leg and skin sensitivity disorders in 65% of cases, and alloplasty in 78% of patients under 6 months have aseptic inflammation of the joint.
2. Within 5 years after the operations under consideration, autografts provide normal (category A + B according to the IKDC – 2000 evaluation scale) more often than allosuchons.
3. The healing processes at the sites of autograft formation (BTB and STG) proceed in the same way with the replacement of defects after 6 months with scar tissue with a clear linear structure.
4. The expansion of bone channels depends on the type of tendon graft, the method of its fixation, and the motor regime in the early postoperative period. In cases of an increase in the diameter of the femoral canal of more than 4.5 mm, it led to a recurrence of anterior instability of the knee joint.
5. During the arthroscopic reconstruction of the ACL, tendon autografts can be recommended, first of all, to young people and patients with a high level of physical activity, and in professional athletes, priority should be given to an autograft from the patellar ligament. Tendon allografts are shown mainly in patients of older age groups who do not play sports.

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