CLINICAL CASE

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RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT WITH CRYOPRESERVED ALLOGENEIC TIBIALIS ANTERIOR TENDON GRAFT

Aim of study. To evaluate the effectiveness of allogeneic tendon, sterilized with supercritical carbon dioxide, in restoration of the anterior cruciate ligament (ACL) during clinical example.

Material and methods. The patient was admitted at the N.V. Sklifosovsky Research Institute for Emergency Medicine with the diagnosis: an old rupture of the anterior cruciate ligament of the right knee joint, rupture of the internal meniscus, chondromalacia of the inner condyle of the right femur 2-3 art., according to the ICRS classification. From the anamnesis, it became known about the previous 2 operations for ruptures of the ligaments of the right knee joint and the use of autologous tendons as a plastic material.

A conversation was held with the patient about all possible methods of ACL repair and a choice was made in favor of using a cryopreserved allogeneic tibialis anterior tendon graft as a graft due to a shortage of autologous tissues. Allogeneic tendons were taken from tissue donors, treated with 10% dimethyl sulfoxide, sterilized with supercritical carbon dioxide and frozen at -80°C. After confirming the absence of toxicity, as well as the results of bacteriological examination, the allogeneic tendon graft was used for ACL repair.

Results. The early postoperative period was uneventful. On the 12th day postoperative wounds healed by primary intention. An MRI examination revealed a graft of the anterior cruciate ligament in the formed bone canals; the graft was not thickened and had a homogeneous structure.

After 28 days, the patient gradually began active and passive development of movements in the knee joint. After 6 weeks the range of motion and strength in the right knee joint was comparable to the left knee joint. After 4 months, according to magnetic resonance imaging, ligamentation of the allogenic graft and "synovial sleeve" formation were observed.

Conclusion. According to the clinical course and time of rehabilitation, the technique of using allogeneic tendons during ACL plastic surgery was comparable to the use of an autologous graft. The clinical experience of using allogeneic tendons at the early postoperative stage could be assessed as successful. Further observation is necessary to fully assess the reconstruction and integration of the tendon.

Keywords: anterior cruciate ligament, arthroscopic repair, graft, tendons, allogeneic, sterilization.

Introduction. Rupture of anterior cruciate ligament (ACL) is a frequent injury among knee joint injuries, which, in the absence of surgical treatment, leads to chronic instability and degenerative changes in the joint [5]. Arthroscopic reconstruction is considered to be the optimal method of surgical treatment of such injuries, which includes replacing the damaged ligament with autologous tissues, allogeneic grafts or synthetic implants. The choice of plastic material depends on the clinical situation, the preferences of the surgeon, and the capabilities of the medical institution [3]. Autologous tissues are the most commonly used material in arthroscopic operations for knee joint ligament ruptures. Nevertheless, this method of plastic surgery does not avoid negative effects, mainly associated with the presence of donor site [1]. The next promising method based on using conserved allogeneic tendons. Conservation process could use freezing, freeze-drying and chemical solutions treatment [4]. Conservation may dramatically change the structure of the tendon tissue, which leads to unsatisfactory strength characteristics of such transplants. Earlier in our publications it was described that penetrating cryoprotectors and their combinations allow preserving the overall architecture of tendons, the structure of collagen fibers and cellular composition, and also do not change the physic-mechanical characteristics of the graft [2]. At the same time, the choice of sterilization method remains an unsolved problem, since known methods (gas sterilization, gamma irradiation, etc.) negatively affect the viability of cells in the graft and indirectly damage of collagen fibers [6]. In our opinion, it is optimal to use supercritical carbon dioxide for sterilization, which allows preserving the structure of biological objects. Preclinical tests have shown sterility, absence of toxicity in cell culture, as well as preservation of physical and mechanical properties and structural integrity of allogeneic tissue that has undergone such treatment. This allowed, on the basis of a positive decision of the local ethics committee, within the framework of scientific work, to proceed to limited clinical trials on the use such transplants in situations, where it is impossible to use autologous material.

The aim of the study is to demonstrate in clinical example the effectiveness of using cryopreserved allogeneic tendon sterilized with supercritical carbon dioxide in the restoration of the anterior cruciate ligament.

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Clinical example. The patient K.V.M., female, born in 2000, was admitted to the Department of emergency traumatology of the musculoskeletal system of N.V. Sklifosovsky Research Institute for Emergency Medicine on 25.09.2022 with the diagnosis: an old rupture of the anterior cruciate ligament of the right knee joint, rupture of the internal meniscus, chondromalacia of the inner condyle of the right femur 2-3 art. according to the ICRS classification (ICD code-10 T93.3).

From the anamnesis: the patient is professionally engaged in sports, in 2018 during the competition she suffered an injury to the right knee joint – a rupture of the posterior cruciate ligament (PCL) and the external collateral ligament (ECL), for which she was operated a few months later. Arthroscopic restoration of the PCL was performed with autograft from the tendons of the popliteal muscles and the external collateral ligament with an autograft from the tendon of the long fibular muscle. A year after the operation and rehabilitation measures, the patient returned to active sports. In 2021 during training, she suffered a repeated injury to her right knee joint. On MRI from 12.04.2022, the following were diagnosed: rupture of the anterior cruciate ligament, linear rupture of the internal meniscus. The grafts in PCL and ECL were not damaged.

Since this injury no longer required emergency surgery, on 09.20.2022 K.V.M. applied for a planned consultation at of N.V. Sklifosovsky Research Institute for Emergency Medicine, where all possible options for surgical treatment, as well as options for plastic materials for ligament restoration, were explained to her. As a result of previously performed operations on the right knee joint to restoring PCL and ECL with tendons of the right lower limb, the patient had a deficiency of autologous plastic material that can be used for plastic surgery of the ACL on the right lower limb. After discussion and the voluntary informed consent of the patient, it was decided to perform plastic surgery with an allogeneic tendon, which was cryopreserved and sterilized with supercritical carbon dioxide. The use of a preserved allogeneic tendon graft (plastic material) for the treatment of patients with ligamentous apparatus defects has been approved by the Committee on Biomedical Ethics of the N.V.Sklifosovsky Research Institute of SP DZM (extract from Protocol No. 6-21 of 06.15.2021).

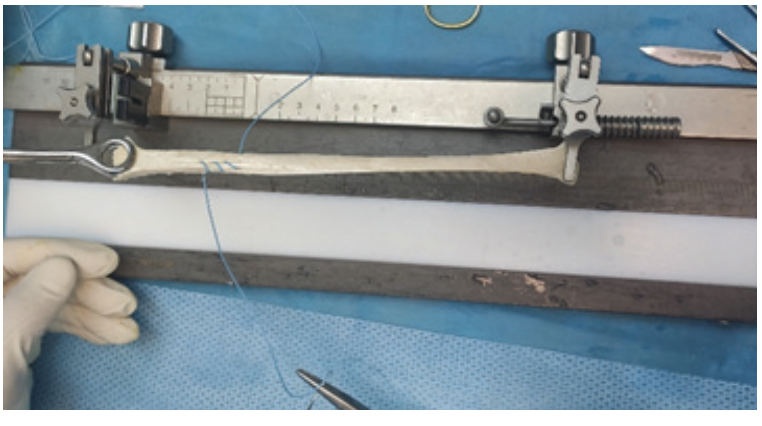
Allogeneic cryopreserved tibial tendon grafts were harvested as part of research work on the basis of the department of tissue preservation and transplant production. Tendon grafts in sterile conditions were explanted and mechanically processed according to the standard operating procedure. Allografts were treated with 10% solution of cryoprotector dimethyl sulfoxide, after that tendons were packed and sterilized with supercritical carbon dioxide. The next step was to freeze the bags with tissues at a temperature of -80 ^{0}C. Satellite samples of allografts, passed all stages of processing together with the transplant, were examined in the culture of multipotent human mesenchymal stromal cells. The prepared allograft was not toxic to the cells and also did not damage their structure. During bacteriological examination, the sterility of the tendon allograft was confirmed. After receiving the results for the absence of hemotransmissive infections in the tissue donor and thanatological examination, the individual transplant was prepared for clinical use (Fig.1).

On 09.26.2022 the patient underwent arthroscopic restoration of the ACL with an allogeneic tendon graft of the anterior tibial muscle sterilized with supercritical carbon dioxide with controlled decompression (Fig. 2,3). Also, during the operation resection of the inner meniscus of the right knee joint was performed. Due to the possible occurrence of conflict between the drilled channel in the tibia and the already formed channel for the PCL, it was decided to slightly change its location.

The early postoperative period proceeded without peculiarities. On the 1st day after operation we performed X-ray control of the position of the titanium but-

Fig. 1. Packed and sterile allogenic tendon graft

a



b

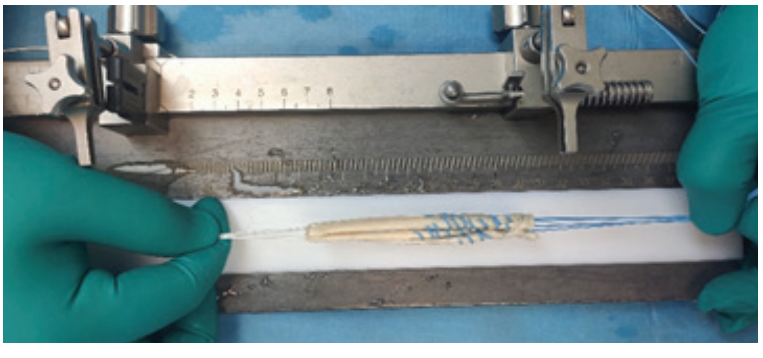


Fig. 2. Allograft preparing before arthroscopic restoration. a – graft stitching, b- graft before insertion into bone channels

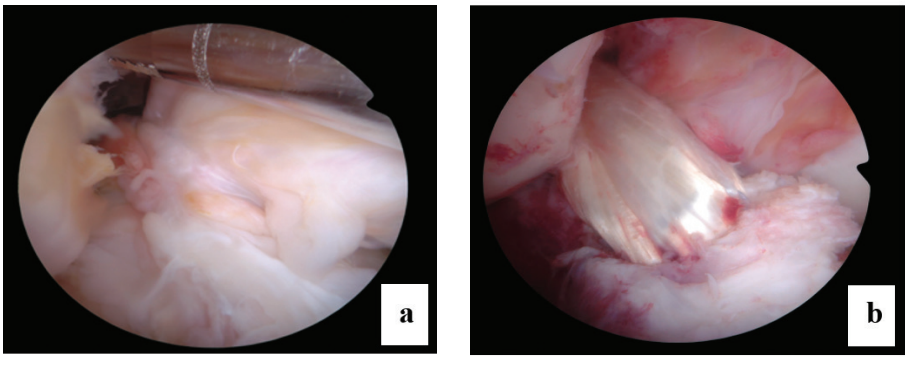


Fig. 3. Arthroscopic picture before (a) and after (b) allograft restoration

tons, fixing graft (Fig. 4). On the X-ray control the position of the fixators and bone channels was satisfactory.

The lower limb was fixed with an adjustable articulated orthosis in the position of full extension of the knee joint for 28 days. To prevent thromboembolic complications from the first day after surgery the patient wore compression knitwear. After receiving the results of ultrasound Dopplerography of veins of the lower extremities from 09.27.2022, on which no echo signs of thrombosis of the veins of the lower extremities were detected, walking with crutches without support on the operated limb was allowed. Also,

Postoperative wounds were treated with 10.25% Povidone-Iodine solution (Fig. 5), and for more effective, rapid reduction of edema, lymphatic drainage applications with kinesiotapes of the knee joint area (Fig. 6) and a standard protocol of therapeutic physical culture were used.

On 12th day the postoperative wounds healed by primary tension, the stitches were removed. After the sutures were removed, myostimulation in TENS (Transcutaneous electrical nerve stimulation) and EMS (Electrical muscle stimulation) modes was used to prepare the thigh and lower leg muscles for movements in the knee joint.

On the 14th day after the operation, the patient underwent magnetic resonance imaging on the GE Signa Hdx 3.0T device, in 3 projections, in T1, T2, PD FS modes. In the formed bone channels allograft is determined, located parallel to the Blumensaat line. The graft is not thickened, homogeneous structure. In PDF mode, trabecular edema of the knee joint bones is detected at the level of metal fixers, the MR signal from paraarticular soft tissues is increased (Fig. 7).

On the 28th day, the patient independently bent the right knee joint by 45° without pain, after which a step-by-step development of movements was

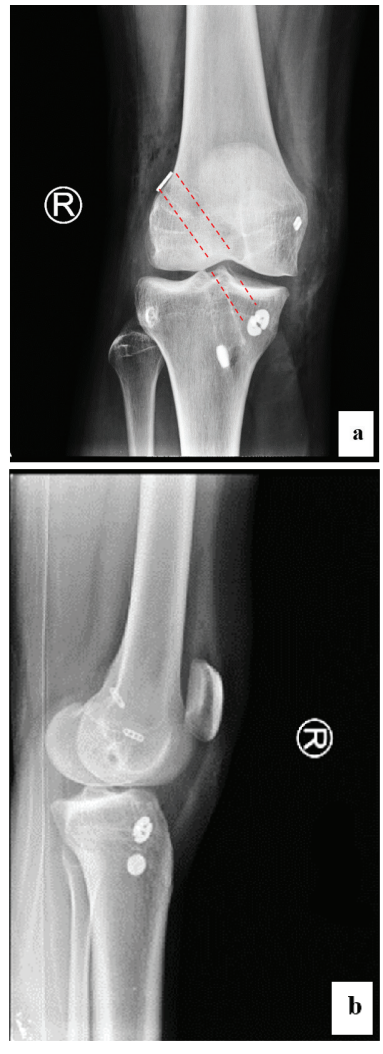


Fig. 4. X-ray examination of the right knee joint in straight (a) and lateral (b) projections, dotted lines show the formed bone channels

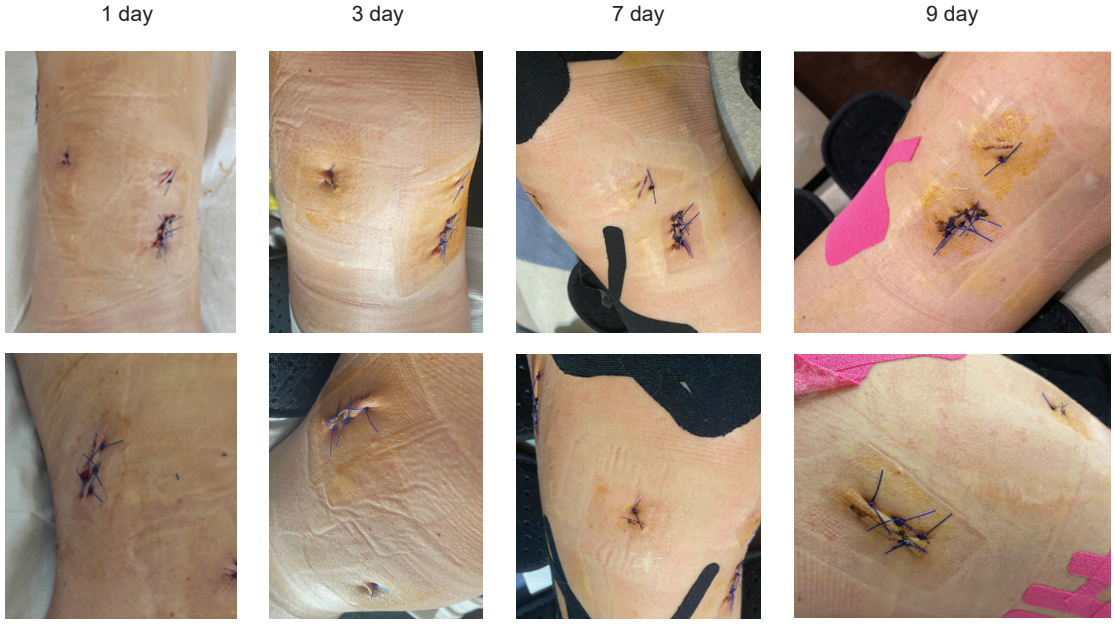


Fig. 5. Dynamic of postoperative wounds reparation Динамика заживления послеоперационных ран. Upper line – top view, lower line– lateral view

Fig. 6. Lymphatic drainage applications with kinesiotapes during injure recover

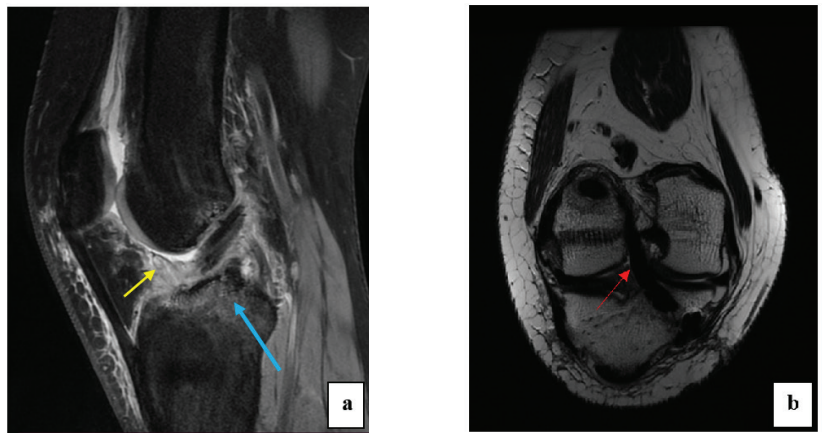


Fig. 7. Magnetic resonance imaging of the right knee joint on the 14th day after surgery: a – increased signal from the pararticular soft tissues (yellow arrow) and bone structures (blue arrow) on PD FS in sagittal projection

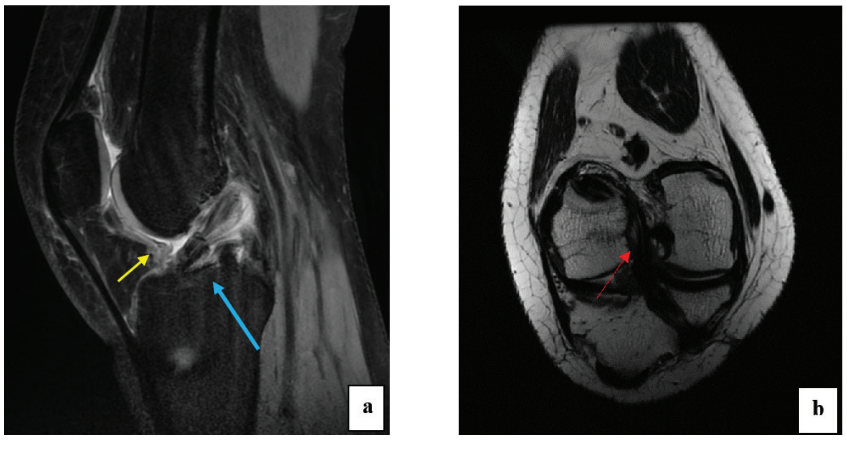


Fig. 8. Magnetic resonance imaging of the right knee joint 4 months after surgery: a – minimal edema of the pararticular soft tissues (yellow arrow) and bone structures (blue arrow) remains on PD FS in sagittal projection; b – an increase in the MR signal from the graft on T2 VI in the oblique coronary projection (red arrow)

started before the onset of pain with a flexion step from 10 to 20 in orthosis. According to the chosen rehabilitation protocol, from that moment on, first metered, and then full support on the lower limb when walking on crutches was offered.

At the end of 5 week the flexion amplitude in the knee joint was 90°, the patient also began to walk without crutches with full support on the right lower limb.

By 7 week the range of motion and strength in the right knee joint was comparable to the left knee joint. At this stage the patient did not complain and returned to her usual lifestyle.

After 4 months, magnetic resonance imaging of the right knee joint was repeated in order to assess tissue rearrangement (ligamentation) and integration of the allograft into the bone channels. The graft is thickened, there is an increase in the MR signal in the T2 VI mode throughout. The fibers are traced with the presence of fluid accumulations in the graft structure. A decrease in paraarticular edema and trabecular edema of bone structures at the level of metal fixators was revealed (Fig. 8). According to the MR study, we assume that the ligamentation of the allogeneic PCC and the formation of the "synovial sleeve" has begun.

Conclusion. This clinical case demonstrates the first experience of using frozen allogeneic graft, treated with cryoprotector and sterilized with supercritical carbon dioxide with controlled gas decompression, in patient with a rupture of the ACL. According to the clinical course and time of rehabilitation, the proposed method of using allogeneic tendons at this stage of observation is comparable to use of autologous graft. But it should be noted that the monitoring of such patients should continue until the complete reconstruction of the tendon and its integration into the bone channels.

The clinical case is demonstrated with the consent of the patient.

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