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THE USE OF THE LONG PERONEAL MUSCLE TENDON AS AN AUTOGRAFT DURING THE PRIMARY PLASTICS OF THE ANTERIOR CRUCIATE LIGAMENT: A SYSTEMATIC REVIEW

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ABSTRACT

The anterior cruciate ligament injuries take the leading place among all the injuries of the knee joint. The rupture of the anterior cruciate ligament most frequently occurs during sports-related and high-energy traumas. The aim of the present systematic review is to compare the results obtained after the anterior cruciate ligament plastics with using the long peroneal muscle tendon and the autograft made from the common tendon of the semitendinous and gracilis muscles. The analysis includes the original articles from the PubMed, Google Scholar, eLibrary, Scopus and Web of Science search systems. The key words for the search included ("peroneus longus tendon" or "fibularis longus tendon") and ("anterior cruciate ligament reconstruction" or "ACL reconstruction"). In the Russian data bases, the same terms were used. From the articles found, the following parameters were extracted: the evaluation of the functional results using the Tegner–Lysholm scale and the questionnaire for subjective assessment of the status among the patients with various knee joint injuries — IKDC (International Knee Documentation Committee); the evaluation of the mean diameter of the autotransplant; the instability of the knee joint; as well as the possible complications; the evaluation of the functions in the ankle joint and the foot using the AOFAS (American Orthopaedic Foot and Ankle Society) and FADI (Foot and Ankle Disability Index) scales. These parameters were used for evaluating the clinical research works on using the autograft made from the long peroneal muscle tendon for the reconstruction of the anterior cruciate ligament. The authors have analyzed the treatment results in 2322 patients which underwent anterior cruciate ligament plastics using the long peroneal muscle tendon (n=1660) and the semitendinous muscle tendon (n=662) autotransplants. The parameters of the postoperative status according to the AOFAS and FADI scales for the long peroneal muscle tendon were 96.47±2.71 and 97.72±2.58, respectively, which does not differ from the uninjured side (p >0.05). The best IKDC scale scores were 94.13±4.66 for the long peroneal muscle tendon and 95.12±0.73 for the semitendinous muscle tendon, while the scores of the Tegner–Lysholm scale were 99.15±2.89 and 99.85±0.37, respectively. Thus, the autograft made using the long peroneal muscle tendon is a proper alternative for the reconstruction of the anterior cruciate ligament, for it is located outside the area of the knee joint.

Keywords: *arthroscopy; anterior cruciate ligament; long peroneal muscle tendon; semitendinous muscle tendon; gracilis muscle tendon.*

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INTRODUCTION

The injuries of the anterior cruciate ligament take the leading place among all the injuries of the knee joint [1]. The rupture of the anterior cruciate ligament is most frequently caused by sports-related and high-energy traumas, for example, motor-vehicle accidents or falling on the knee, in which the foot is positioned with plantar flexion [2]. The anatomic reconstruction of the anterior cruciate ligament is a modern gold standard for restoring the stability in the knee joint, for decreasing

ПРИМЕНЕНИЕ СУХОЖИЛИЯ ДЛИННОЙ МАЛОБЕРЦОВОЙ МЫШЦЫ В КАЧЕСТВЕ АУТОТРАНСПЛАНТАТА ПРИ ПЕРВИЧНОЙ ПЛАСТИКЕ ПЕРЕДНЕЙ КРЕСТООБРАЗНОЙ СВЯЗКИ: СИСТЕМАТИЧЕСКИЙ ОБЗОР

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АННОТАЦИЯ

Повреждения передней крестообразной связки занимают лидирующее место среди всех травм коленного сустава. К разрыву передней крестообразной связки чаще всего приводят спортивные и высокоэнергетические травмы. Цель настоящего систематического обзора — сравнить результаты пластики передней крестообразной связки при помощи сухожилия длинной малоберцовой мышцы и аутотрансплантата из сухожилия полусухожильной и нежной мышц. Проанализированы оригинальные статьи из поисковых систем PubMed, Google Scholar, eLibrary, Scopus и Web of Science. Ключевые слова для поиска включали «peroneus longus tendon» or «fibularis longus tendon» и «anterior cruciate ligament reconstruction» or «ACL reconstruction». В русскоязычных базах данных использовали аналогичные термины. Из статей извлечены следующие параметры: оценка функциональных результатов по шкале Тегнера–Лисхольма и опроснику для субъективной оценки состояния пациентов с различными повреждениями коленного сустава IKDC (International Knee Documentation Committee); оценка среднего диаметра аутотрансплантата; нестабильность коленного сустава; возможные осложнения; оценка функции голеностопного сустава и стопы по шкалам AOFAS (American Orthopaedic Foot and Ankle Society) и FADI (foot and ankle disability index). Эти параметры применялись для оценки клинических исследований использования аутотрансплантата из сухожилия длинной малоберцовой мышцы для реконструкции передней крестообразной связки. Авторами проанализированы результаты лечения 2322 пациентов, которым была выполнена пластика передней крестообразной связки с использованием аутотрансплантатов из сухожилия длинной малоберцовой мышцы (n=1660) и сухожилия полусухожильной мышцы (n=662). Показатели послеоперационного состояния по шкалам AOFAS и FADI для сухожилия длинной малоберцовой мышцы составили 96,47±2,71 и 97,72±2,58 соответственно, что не отличается от здоровой стороны (p >0,05). Лучшие баллы по шкале IKDC составили 94,13±4,66 для сухожилия длинной малоберцовой мышцы и 95,12±0,73 для полусухожильной мышцы, по шкале Тегнера–Лисхольма — 99,15±2,89 и 99,85±0,37 соответственно. Таким образом, аутотрансплантат из сухожилия длинной малоберцовой мышцы является подходящей альтернативой для реконструкции передней крестообразной связки, так как находится вне области коленного сустава.

Ключевые слова: *артроскопия; передняя крестообразная связка; сухожилие длинной малоберцовой мышцы; сухожилие полусухожильной мышцы; сухожилие нежной мышц.*

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the rates of secondary ruptures of the menisci and, as a result, for decreasing the rates of post-traumatic osteoarthritis [3, 4]. For performing the reconstruction of the anterior cruciate ligament, an autotransplant or an allotransplant or a synthetic prosthesis is required. The autograft made of the semitendinous and gracilis muscle tendons (SGMT (in Russian: СПНМ) is the most commonly used transplant for the reconstruction of the anterior cruciate ligament worldwide [5]. Along with the SGMT, other used autotransplants include the bone-patellar tendon-bone and the tendon of the quadriceps muscle, however, all of the abovementioned variants are associated with complications, in particular, the instability of the knee joint or the quadriceps/hamstring-imbalance, pain in the area of the patella and of the thigh, contractures of the knee joint and patellar fractures [6-8.]. In case of multiple injuries of the ligamentous apparatus of the knee joint, the SGMT autotransplant can be insufficient for the plastics of all the damaged structures. In a number of countries, the use of allotransplants and synthetic transplants is not possible [8]. Within this context, currently the surgeons more often use the alternative autografts for the anterior cruciate ligament plastics — the ones made from the long peroneal muscle tendon (LPMT) [9].

The use of the LPMT as an autograft for the reconstruction of the anterior cruciate ligament was first described by S. Kerimoğlu et al. in 2008 [10]. In 2012, J. Zhao et al. [11] have also demonstrated the efficiency of using LPMT as an autograft. In a research work performed in 2017 by R. Lukman et al. [12], the biomechanical properties of the SGMT and LPMT were studied *ex vivo*. Based on the research results, there was no significant difference in the tensile strength between the LPMT (446.1N±233.2N, where N is the force in newtons) and the quadruple SGMT transplant (405.8N±202.9N) with a similar cross-sectional area. In 2021, J. He et al. [12] have described the LPMT autograft as the comparable alternative option to the SGMT one from the point of view of the functional results, also, the authors have concluded that the use of the LPMT autograft provides better clinical results in the knee joint, expressed as the decrease in the knee joint pain syndrome and thigh muscle weakness, however, the assessment by the American Orthopaedic Foot & Ankle Society (AOFAS) was much lower comparing to the preoperational one [14].

The results of the abovementioned research works confirm that the LPMT autograft is a strong donor tissue for reconstructing the anterior cruciate ligament. Later on, a large cohort of clinical research works [15–21] have demonstrated good clinical results and minimal pain in the area of the autotransplant installation, by this proving the efficiency of using the LPMT as an autograft, nevertheless, the variability of the methods and parameters in various research works, as well as small number of cases in each research, add to the uncertainty, especially when comparing the results between various transplants [21].

This systematic review was carried out for the purpose of comparing and analyzing the results of anterior cruciate ligament plastics using the LPMT in terms of restoring the functions and the biomechanics of the knee joint and of the foot with restoring the knee joint stability, in the aspect of pain or paresthesia in the area of the transplant application, its survival rate, also included were the clinical research works, comparing the LPMT and SGMT autotransplants during the reconstruction of the anterior cruciate ligament [22].

METHODOLOGY OF SEARCHING THE SOURCES

The systematic review was compiled in accordance with recommendations of the PRISMA international protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) issued on March 1, 2020 [23]. The research includes original articles, containing data with full text in English or Russian languages, accessible in the Internet (search systems: PubMed, Google Scholar, eLibrary, Scopus and Web of science) from 2018 until 2024. During the search, the following key words were used: (“peroneus longus tendon” or “fibularis longus tendon”) and (“anterior cruciate ligament reconstruction” or “ACL reconstruction”), while for the Russian data bases — “long peroneal muscle tendon”, “anterior cruciate ligament plastics” or “the use of long peroneal muscle tendon during the anterior cruciate ligament plastics”. The publications were informing about the clinical research works on the reconstruction of the anterior cruciate ligament (single-bundle or double-bundle) using the LPMT autotransplant (the anterior half or its whole thickness), the research works, in which direct comparison was made between the results of using the LPMT and the SGMT, as well as about the biomechanical research works. All the surgeries were initial, performed due to the onset of acute or chronic damage of the anterior cruciate ligament, with or without the meniscus damage.

The review did not include irrelevant articles or non-original research works, such as literature reviews, editorial opinions, corrections, meta-analyses, as well as publications, which contained the research

on allotransplants and research works analyzing the results after the reconstruction of other ligaments outside the knee joint using the LPMT autotransplant.

Quality assessment

For the evaluation of methodological quality of the research works included in the review, we have used the Methodological Index for Non-randomized Studies (MINORS), as well as a set of specialized instruments for quality evaluation developed in 2013 by the National Heart, Lung and Blood Institute (NHLBI).

Extraction and analysis of data

The parameters analyzed in this review were reflecting the functional results, including the mean points of the Lysholm scale, in which the percentage of points was more than 84 (excellent or good result); the mean subjective point of the International Knee Documentation Committee (IKDC) and the percentage of normal or almost normal subjective IKDC points; the mean diameter of the autotransplant; the instability of the knee joint, including the percentage of negative anterior drawer test cases; the possible complications, including paresthesia or pain syndrome in the area of the graft installation and the rates of unsuccessful transplantations; the results of treating the developing abnormalities of the foot and of the ankle joint after extracting the LPMT, including the mean parameters before and after surgery, assessed using the American Orthopaedic Foot and Ankle Society scale (AOFAS) and the Foot and Ankle Disability Index (FADI), as well as the evaluation of the biomechanical parameters of the foot and of the ankle joint.

All the data collected by us were presented in tables; a formal meta-analysis was carried out using the RevMan software (version 5.4, Cochrane Collaboration). Continuous variables were extracted and analyzed as the mean values with standard deviation (Standard Deviation, SD). The standard deviation was calculated using the available data in accordance with previously approved formula: [(the highest value of the range — the least value of the range)] or (interquartile range / 1.35). If the standard deviation was impossible to calculate using this approach, the highest standard deviation was used. For continuous variables, the mean difference (MD) was calculated along with the 95% confidence interval (95% CI).

We have also checked the sample heterogeneity using the χ^2 and Higgins I^2 tests. According to the Cochrane recommendations, the mean heterogeneity was calculated in case of I^2 >30% or p <0.5. We have used the conservative statistical approach, applying the Mantel–Haenszel random effects model in case of having the mean heterogeneity and the fixed effects model for cases when the p values were <30% and >0.5, respectively. The statistically significant p level was <0.5 for all the results.

LITERATURE SEARCH, SELECTION OF RESEARCH WORKS AND THEIR CHARACTERISTICS

Initially, as a result of literature search, a total of 927 articles were found (Fig. 1) [23]. After excluding the duplicate publications, 917 articles were remaining, while after screening the titles and abstracts — 26 articles were obtained, the full texts of which were verified for conformity to the inclusion criteria. All the selection criteria after the double-staged screening were met by 21 articles [24–43]: 16 articles, which were reporting about the results of reconstructing the anterior cruciate ligament using the LPMT autotransplant, and 5 articles, in which comparison was made for the results of using LPMT and SGMT autografts. All the articles (n=21) were compiled into a summary table (table 1). The total set of analyzed results included 2322 patients, of which 1660 had a reconstruction of the anterior cruciate ligament using the LPMT autotransplant, while the results for remaining 662 patients were extracted from the publications, in which comparison was made for the use of LPMT and SGMT autografts.

Assessment of the autotransplant diameter

Of the 21 research works included into the literature review, 16 have described using the whole thickness of the LPMT, while 5 have used the anterior LPTM part. In 8 publications, the mean transplant diameter was evaluated in 520 patients. In 5 research works, in which the LPMT and SGMT were compared [22, 40–43], the mean diameter of the LPMT autotransplant was significantly higher comparing to the SGMT transplant. The research by G. Wierer et al. [43] has also investigated the inter-relation of the body mass index and of the hip and shin circumference with the transplant diameter. Based on the research results, it was found that the body mass index and hip circumference parameters affected only the diameter of the SGMT transplant, while the shin circumference and body mass index had no significant effect on the LPTM transplant diameter. However, based on the results from the research work by D. Ertilav [31], a statistically significant correlation was found between the weight of the patient, the height, the body mass index, the length of the lower limb, the hip circumference, the shin circumference

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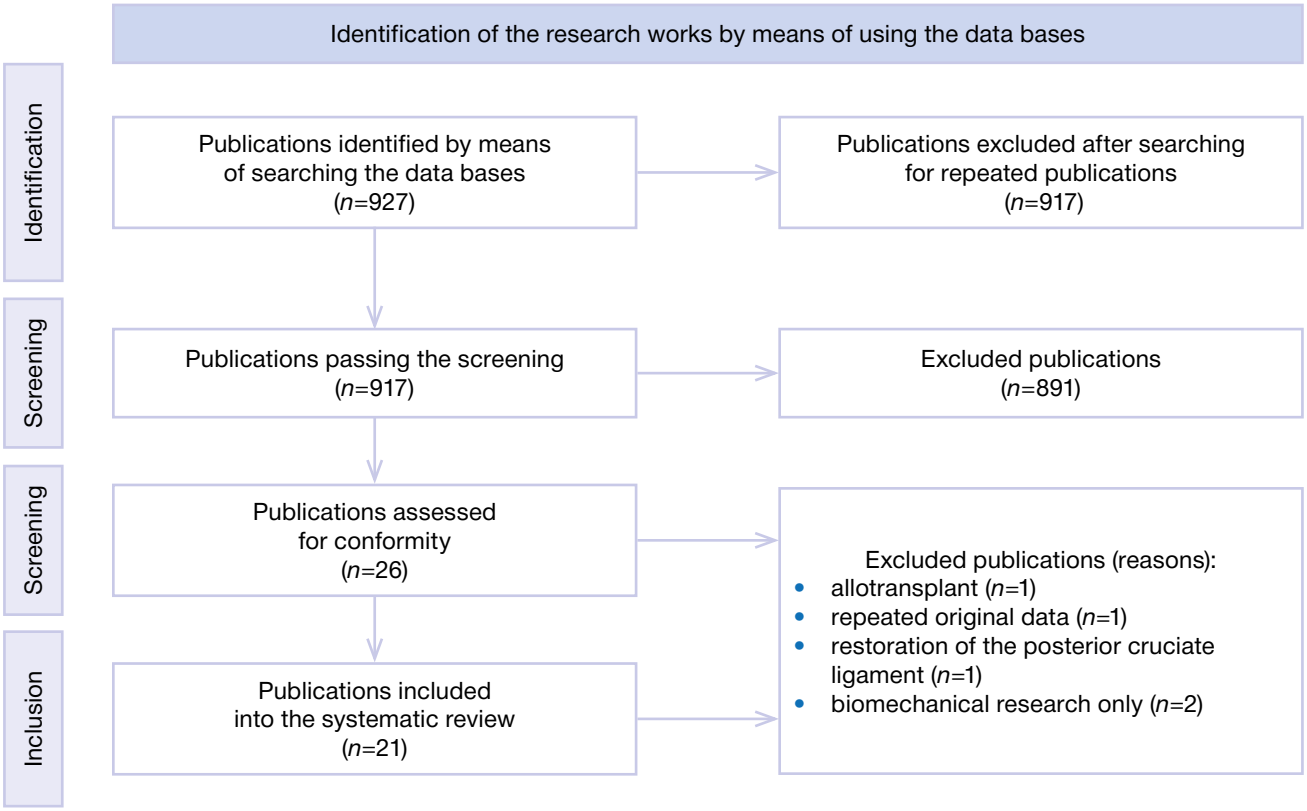

Fig. 1. Literature search diagram [23].

and the transplant diameter. In the research works evaluating the LPMT autotransplant diameter, the mean dimension was 7–9 mm.

Evaluation of the results using the American Orthopaedic Foot and Ankle Society (AOFAS) scale and the Foot and Ankle Disability Index (FADI)

Using the scale compiled by the American Orthopaedic Foot and Ankle Society (AOFAS) and using the Foot and Ankle Disability Index (FADI), a total of 1000 of patient data sets were analyzed with the patients operated using the LPMT (table 2). The post-operative mean AOFAS scores on the side of LPMT extraction were comparable to the mean values of the FADI index, with the difference from the uninjured side being statistically insignificant ($p > 0.05$). This have demonstrated good functional results and the possibilities of safely using the LPMT as an autograft without significantly affecting the functions of the foot and of the ankle joint.

Evaluation of the flexion and extension force in the ankle joint

In a series of clinical cases from S. Rhatomy et al. [33], a complex approach was used to evaluate the functions of the foot and of the ankle joint during the postoperative period. The results of muscle strength tests were collected in 31 patients in 6 months after surgery. For the purpose of measuring the isometric muscle strength, the patients were using the special hydraulic double-acting dynamometer. A research was conducted on the bilateral angled eversion and plantar flexion of the great toe. Each measurement of the muscle strength was carried out 3 times with registering the highest value. Foot eversion was measured in lying position. Based on the results of muscle strength testing, the mean foot eversion force was 65.87±7.63N in the area of the autotransplant installed and 66.96±8.38N on the unaffected side. The mean strength of plantar flexion was 150.64±11.67N on the side of the autograft installed and 152.10±12.16N on the unaffected side. As a result of this research work, no difference was observed in the strength of foot eversion and plantar flexion between the operated and the uninjured side.

Evaluation of the functions and stability of the knee joint

A total of 336 results of LPMT autotransplantations and 326 SGMT autotransplantations were analyzed.

Table 1

Publications selected for analysis

Author	Year	Country	Study design	Gender: males/ females	Age (min–max), years	Follow-up period, months (SD)	Tendon used
Research works with using only the long peroneal muscle tendon (LPMT) as an autograft							
[24]	2020	China	Retrospective	19/16	18–60	6.5±3.61	Layered
[25]	2023	China	Retrospective	55/32	20–45	24.5±14	Layered
[26]	2021	China	Case series	13/8	18–45	6.5±3.61	Anterior part
[27]	2023	Turkey	Retrospective	74/8	16–66	46.6±30.3	Layered
[28]	2019	Vietnam	Case series	19/11	18–51	14.5±8.22	Anterior part
[29]	2023	Bangladesh	Prospective	348/91	18–45	12.5±7.1	Layered
[30]	2020	Indonesia	Cohort, retrospective	59/16	18–45	5±2.74	Layered
[31]	2021	Turkey	Retrospective	38/14	17–51	12±6.8	Layered
[32]	2022	India	Prospective	78/35	17–39	11.5±6.5	Layered
[33]	2019	Indonesia	Case series	22/9	18–45	11.5±6.5	Layered
[34]	2022	India	Case report	1, male	25	12	Layered
[35]	2021	India	Prospective	36/12	18–36	17±9.67	Layered
[36]	2020	Russia	Prospective	407/171	35.29±12	24.5±14	Layered
[37]	2020	China	Prospective	20/12	16–45	6.5±3.61	Layered
[38]	2018	China	Prospective	11/5	35–65	27±15.44	Layered
[39]	2024	China	Prospective	6/14	18–44	4±2.16	Anterior part
Research works comparing the results of using the long peroneal muscle tendon (LPMT) and the semitendinous and gracilis muscles tendon (SGMT)							
[22]	2019	Indonesia	Prospective	Hamstring group: 24/4 Peroneus longus group: 20/4	16–45	12.5±7.1	Layered
[40]	2023	Pakistan	Prospective cohort	138/20 (158), of which peroneus longus: 85; hamstring: 73	18–51	36.5±20.92	Layered
[41]	2023	India	Prospective cohort	Hamstring group: 57/39 Peroneus longus group: 68/30	16–50	10±5.63	Layered
[42]	2022	Iran	Comparative cross-section	Hamstring group: 58/7 Peroneus longus group: 61/4	18–50	12.5±7.1	Layered
[43]	2023	Austria	Cross-section	Hamstring group: 64 Peroneus longus group: 64	18–45	6.5±3.61	Anterior part

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Table 2

Comparison of the results of the AOFAS and the FADI scales

Source	Number of patients	AOFAS scale	FADI scale
[25]	87, divided by body mass index: normal excessive obesity	In the first two groups, there were no significant differences in the AOFAS scores after surgery. In Group 1 — 94.61±3.48; in Group 2 — 94.00±3.82. In patients from Group 3, the values were lower — 89.47±3.37	-
[29]	439	Mean score — 97.63±3.20 (range 89.00–100.00)	Mean score — 98.46±2.31 (range 86.20–100)
[37]	32	Mean score — 94.7±6.8	-
[26]	21	Mean score — 96.8±3.01	Mean score — 97.6±2.66
		Post-operative results, assessed in 3 years, comparable with pre-operational data	
[27]	82	On the side of autotransplant extraction — 98.7±3.3 (range 87–100); on the contralateral side — 100	-
[33]	31	Mean score — 98.71±3.03 on the side of the autograft extraction and 99.03±3.00 on the contralateral uninjured side	Mean score 99.71±0.57 on the side of the autograft extraction and 99.71±0.61 on the contralateral uninjured side
		Based on the research results, no significant difference was shown for the AOFAS and FADI scores between the extraction side and the contralateral side	
[35]	48	Mean score — 98.4±1.23	-
[28]	30	Function of the ankle joint and foot before surgery — 97.3±1.67, after surgery — 97.3±1.54 (lesser score — 93, maximal — 100)	-
[30]	75	Mean score — 98.93±3.10	Mean score — 99.79±0.59
[42]	65	Mean score on the side of the transplant extraction — 93.42±1.7 (range 84–100; “excellent” — 90–100 points, “good” — 75–89 points, “satisfactory” — 60–74 points, “poor” — <60 points). Comparing to the uninjured side, no difference was observed	Mean score on the side of the transplant extraction — 92.78±0.57 (range 94–102) and 98.91±0.62 on the unaffected side. No significant difference comparing to the unaffected side
[41]	98	Mean score — 96.2±0.95, in 12 months — 99.05±3.56	-
[22]	24	Mean AOFAS score — 97.3±4.2	Mean FADI score — 98±3.4
[39]	20	Mean AOFAS score on the operated side — 98.05±1.73, on the unaffected side — 98.30±1.66	-

In the research work by A. Agarwal et al. [41], 98 patients were operated using the LPMT and 96 — using the SGMT. The results of the anterior drawer test in 187 patients in both groups in 12 months after surgery were negative. The “+” test result was reported for 6 patients. A single patient from the LPMT group had a (+++) positive anterior drawer test due to a repeated injury. According to the Lachman test data, 177 patients had a negative test result in 12 months; 16 patients had a positive test result. The functional results were evaluated using the IKDC and Lysholm scales (table 3).

In a research by S. Rhatomy et al. [22], an evaluation of the results registered before surgery and in 12 months after surgery using the Lysholm and IKDC scales was carried out in 28 patients, in which the SGMT autograft was used, as well as in 24 patients with the LPTM autograft used. Based on the research results,

no significant differences were observed between the Tegner–Lysholm and IKDC scores before surgery and after a 1 year of follow-up (p >0.05).

No significant differences were observed in the publications which have compared the LPMT and SGMT using the IKDC and Tegner–Lysholm scales. The Lachman test has shown satisfactory results in the majority of patients.

Thus, no statistically significant (p >0.05) differences were reported between two groups with the SGMT and LPMT autotransplants in terms of the functional parameters and stability parameters of the knee joint.

Complications

In the research work by U. Yadav et al. [34], a single clinical case was reported that was associated with iatrogenic neurological deficit in the foot after the extraction of the LPTM autotransplant. Surgical revision of the common peroneal nerve was performed for the purpose of ruling out the nerve damage when using the stripper. The revision surgery has revealed the presence of an intraneural hematoma. The nerve decompression was carried out by means of neurolysis. During further patient follow-up, the function of the anterior cruciate ligament was deemed satisfactory. The functioning of the patient's foot has completely restored in 3 months.

In a retrospective research by A. Cakar et al. [27], 15 patients had hypoesthesia along the dorsal-external surface of the foot and distally from the surgery scar in the area of the lateral malleolus, while 2 patients had hyperalgesia in the area of the distal part of the scar. Two cases of compartment syndrome were described, in both cases fasciotomy was carried out with complete regress of symptoms in 5 days. One patient had experienced a transient peroneal nerve injury and a neurological deficit in the foot: the functions have restored in 6 months.

CONCLUSION

Our research did not detect statistically significant differences (p >0.05) when using the Tegner–Lysholm and IKDC scales comparing to the SGMT autotransplant, also revealing a slight and statistically insignificant (p >0.05) decrease of AOFAS and FADI scores after extracting the LPTM autograft. Thus, it is deemed justified to make a conclusion that the LPMT autograft is a good alternative material for the reconstruction of the anterior cruciate ligament.

ADDITIONAL INFORMATION

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Table 3

Comparative results on the IKDC and Tegner–Lysholm scales

Source	Number of patients	AOFAS scale	FADI scale
[40]	85 — LPMT 73 — SGMT	In the group using the LPMT autotransplant — 57.98±6.98, in the SGMT group — 58.34±5.57	In the group using the LPMT autotransplant — 61.78±4.41, of SGMT — 62.76±2.99
		In 6 months of follow-up in LPMT patients, the subjective function of the knee joint was significantly better than in a group of SGMT patients	
[41]	98 — LPMT 96 — SGMT	In the LPMT group: in 6 months — 83.28±3.71 in 12 months — 94.13±4.66 In the SGMT group: in 6 months — 79.73±6.83 in 12 months — 95.12±0.73	In the LPMT group: in 6 months — 97.00±0.00 in 12 months — 99.15±2.89 In the SGMT group: in 6 months — 96.35±1.60 in 12 months — 99.85±0.37
[42]	65 — LPMT 65 — SGMT	In the SGMT group: before surgery — 54.8±8.5 after surgery — 93.4±6.2 In a group of LPMT patients: before surgery — 55.2±2.4 after surgery — 92.5±9.8	-

Note. LPMT — long peroneal muscle tendon; SGMT — semitendinous and gracilis muscles tendon.

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