ISSN 0030-5987. Orthopaedics, traumatology and prosthetics. 2021. № 4

УДК 616.728.3-089.844-089.2(045)

DOI: http://dx.doi.org/10.15674/0030-59872021413-21

Results of minimally invasive knee posterolateral corner reconstruction

M. L. Golovakha [1], S. A. Bondarenko [2], W. Orljanski [3]

[1] Zaporizhzhia State Medical University. Ukraine
[2] «Motor Sich» Clinic, Zaporizhzhia. Ukraine
[3] Vienna Private Clinic. Austria

Posterolateral rotational knee instability is one of the insufficiently studied problems of modern orthopedics. Complexity of anatomy, difficulties of diagnosis together with a small number of such injuries did not allow to formulate a clear concept and algorithm for the treatment of such patients. Only in the last 10 years, this problem has been given attention. The paper describes a new minimally invasive technique of posterolateral corner reconstruction under arthroscopic control. Objective. To analyze the long-term results of minimally invasive posterolateral corner reconstruction under arthroscopic control. Methods. The results of treatment of 58 patients were presented, 26 of them formed a study group and 32 — comparison. The dynamics of the pain syndrome, the nature of range of motion restoration, as well as tests of rotational stability were assessed. Results. Statistical analysis of long-term results showed that pain syndrome after minimally invasive technique is significantly lower, and the function of the knee in dynamics recovers faster. The results of knee lateral stability were better in the study group. The main classification of posterolateral corner injuries by Fanelli and Larson is mostly consistent with clinical practice. However, it does not take into account clinical cases of anterior cruciate ligament ruptures combined with injuries of the posterolateral corner. Conclusions. The use of the proposed method of minimally invasive knee posterolateral corner reconstruction with arthroscopic grafting of the popliteal tendon provided positive short-term and long-term results of treatment of patients, reduction of pain intensity after surgery and earlier recovery of range of motion in the knee. An increase complications and deterioration of function was not detected in any case. Key words. Knee, arthroscopy, cruciate ligament, structures of the posterolateral corner, instability.

Задньолатеральна ротаційна нестабільність колінного суглоба є однією з недостатньо вивчених проблем сучасної ортопедії. Складність анатомії, труднощі діагностики разом із невеликою кількістю таких травм не дозволили сформулювати чітку концепцію й алгоритм ведення таких пацієнтів. Лише останні 10 років цій проблемі почали приділяти належну увагу. У роботі описано нову малоінвазивну методику пластики структур задньолатерального кута колінного суглоба під артроскопічним контролем. Мета. Провести аналіз віддалених результатів малоінвазивного відновлення структур задньолатерального кута під артроскопічним контролем. Методи. Вивчено результати лікування 58 пацієнтів, 26 з яких склали групу дослідження і 32 — порівняння. Оцінено динаміку больового синдрому, характер відновлення обсягу рухів, а також тести ротаційної стабільності. Результати. Статистичний аналіз віддалених результатів показав, що больовий синдром після операції, виконаної за малоінвазивною методикою істотно нижчий, а функція колінного суглоба в динаміці відновлюється швидше. Результати відновлення задньолатеральної стабільності колінного суглоба кращі в групі дослідження. Основну класифікацію ушкоджень структур задньолатерального кута за Fanelli і Larson було розроблено для діагностики задньолатеральної нестабільності, вона здебільшого відповідає клінічній практиці. Проте не враховує клінічні випадки розриву передньої схрещеної зв'язки в поєднанні з ушкодженнями структур задньолатерального кута. Висновки. Використання запропонованої методики малоінвазивного відновлення структур задньолатерального кута колінного суглоба з артроскопічною реконструкцією сухожилка підколінного м'яза забезпечило позитивні найближчі та віддалені результати лікування пацієнтів, зменшення інтенсивності болю після операції та швидше відновлення обсягу рухів у колінному суглобі. Збільшення кількості ускладнень і погіршення функції кінцівки не виявлено в жодному випадку. Ключові слова. Колінний суглоб, артроскопія, схрещена зв'язка, структури задньолатерального кута, стабільність.

Key words. Knee, arthroscopy, cruciate ligament, structures of the posterolateral corner, instability

Introduction

Diagnosis and treatment of combined posterior cruciate ligament (PCL) and posterolateral angle injuries is an urgent problem. It is not for nothing that in modern literature the posterolateral part of the knee joint is called «the dark side of the knee», because there are many questions concerning the study of anatomy, biomechanics and methods of reconstruction of these structures. Evaluation of the clinical outcomes of treatment of patients with such injuries remains unclear. Injuries to the posterolateral angle can be either isolated or combined with ruptures of the anterior and posterior cruciate ligaments. The role of damage to posterolateral structures in combination with PCL rupture has been repeatedly described [1–5].

PCL injury and related posterior and posterolateral knee instability are one of the most controversial topics in the spectrum of orthopedic knee impairments. This is primarily due to the relatively low incidence of PCL injuries (3–6 % of all impairments of the ligaments).

Currently, many experts support the view that PCL damage is most often combined with injuries of the structures of the posterolateral angle and causes not only posterior but also posterolateral rotational instability [6–8]. The concept of «posterolateral angle» appeared relatively recently, in the 1980s [4]. For a long time, the posterolateral angle and its structures were considered a «dark spot» in the functional anatomy of the knee joint. Only the most recent research has made it possible to form a clear idea of its structure [6]. Restoration of all three of these structures (including the arcuate ligament) in addition to PCL plastic surgery has been called «anatomical reconstruction of the posterolateral angle» in the literature [9, 10]. To date, more than 10 different approaches of posterolateral angle plastic surgery have been proposed [11]. Undoubtedly, the increased attention to these structures and to the restoration of rotational stability reflects a desire to improve the long-term outcomes of treatment of patients with chronic posterior instability. Restoration of several stabilizing ligaments of the knee joint requires a significant amount of plastic material and the use of allogeneic tendons [12]. In addition, most modern techniques are quite traumatic and cause full-fledged wide access to the lateral surface of the knee joint. Many authors note that open posterior lateral plasticity is associated with a risk of complications such as tibial nerve damage, tibial head fracture, and bone graft tunnel crossings [13, 14].

A typical mechanism of damage to these structures is injury during simultaneous bending of the knee joint and foot, as well as excessive external rotation of the tibia in varus or valgus deviation. In addition, posterior lateral structures may be affected by hyperflexion or hyperextension of the lower leg. The anatomical components of the structure include (Fig. 1): posterior horn of the lateral meniscus, *lig. meniscofemorale anterius, lig. meniscofemorale posterius, lig. collaterale fibulare,* lateral head of *m. gastrocnemius, lig. popliteum obliquum, lig. popliteum arcuatum* and *lig. popliteofibulare,* posterolateral capsule and *m. popliteus* tendon attachment site. These structures and their localization can be variable [2, 11, 15, 16]. According to modern biomechanical studies, there are three key structures of the posterolateral angle that provide varus and external rotational stability of the knee joint. *Lig. collaterale fibulare* is the primary stabilizer of varus opening and the secondary limiter of posterolateral rotation of the tibia relative to the femur. *Lig. popliteofibulare* is the passive stabilizer of external tibial rotation. *M. popliteus* with tendon act both as a static and dynamic stabilizer, controlling the lateral rotation of the tibia.

At the same time, a stable approach has been formed, where the structures of the posterolateral angle are considered as PCL agonists and justify their mandatory restoration during its reconstruction. However, in practice we encounter both isolated injuries of the structures of the posterolateral angle and the combination with rupture of the anterior cruciate ligament (ACL). It should be noted that isolated injuries of the posterolateral angle are relatively rare and account for 1.6–2.8 % of all knee injuries. Insufficient attention to the disruption of these structures with ruptures of both anterior and posterior cruciate ligaments has been shown to lead to unsatisfactory treatment outcomes in patients [1, 2, 6, 18, 19]. Con-

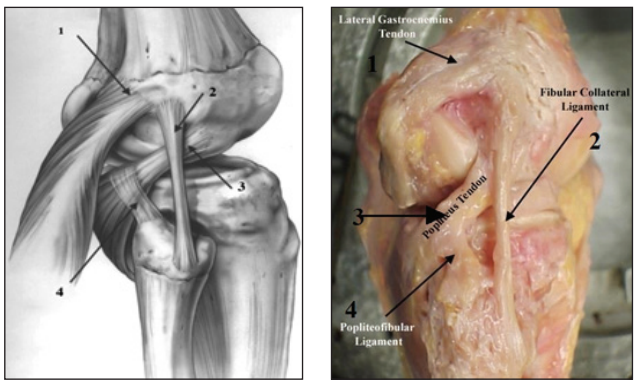

Fig. 1. Anatomical structures of the posterolateral angle of the knee joint: 1 — *m. gastrocnemius*, 2 — *lig. collaterale fibulare*, 3 — tendon *m. popliteus*, 4 — *lig. popliteofibulare* [17]

comitant damage to the secondary knee stabilizers is often overlooked when focusing on cruciate ligament repair. An incompletely eliminated rotational component results in both subjective and objective instability of the knee joint and causes recurrence of posterior instability due to graft overload.

Currently, there is no consensus on the diagnosis and treatment of rotational instability of the knee joint due to damage to the posterolateral angle, there is no comprehensive approach to restoring joint stability, taking into account all components of this pathological process. Techniques for restoring the posterolateral angle of the knee joint are complex and traumatic. Therefore, reconstruction of the anterior or posterior cruciate ligaments does not always involve reconstruction, and operations in conditions of isolated posterolateral instability are generally performed very rarely. Therefore, the introduction into clinical practice of minimally invasive method of reconstruction of these structures is relevant. The first experience with the use of arthroscopic techniques to restore the popliteal tendon [20, 21] has reduced the trauma of this surgery.

The aim of the study: to assess the long-term results of minimally invasive restoration of the structures of the posterolateral angle under arthroscopic control.

Material and methods

Clinical material

The study was approved by the local Committee on Bioethics (Commission on Bioethics of Zaporizhia State Medical University, Minutes No. 7 of 26.10.2017). Informed consent was obtained from all patients included in the study. A total of 75 patients were monitored, of whom 58 were examined 2 years after surgery. Thus, the study included 58 patients with posterolateral rotational instability of the knee joint, operated in the period from 2006 to 2019 at Zaporizhia Regional Clinical Hospital «Motor Sich Clinic» (Zaporizhia).

Patients were divided into two groups depending on the method of reconstruction of the posterolateral angle structures: the study group (26 subjects, 44.8 %) with minimally invasive restoration of structures under arthroscopic control; comparison group (32, 55.2 %) with restoration of the posterolateral angle in an open technique [22, 23]. The distribution of patients was performed according to the Fanelli-Larson classification [15].

Both groups were homogeneous in sex and age. There were 43 men (74.1 %) and 15 women (25.9 %). Distribution of patients by age: 2 (3.5 %) up to 20 years, 18 (31.0 %) — 21–30, 22 (37.9 %) — 31–40, 16 (27.6) %) over 40. The mean age of patients was 32 years (18–48). Patients were operated on at different times after injury, from 2 weeks to 3 years. All operations were performed by one surgeon. The distribution of patients with combined impairment of the knee joint was carried out taking into account the Fanelli-Larson classification [15] and is given in Table 1.

Features of clinical examination

A diagnostic algorithm was used, which includes clinical tests and additional instrumental examinations to more accurately determine the degree of posterior and posterolateral instability, important for the choice of treatment tactics for such patients.

When static knee stabilizers are injured, dynamic ones cannot function properly. Posterolateral instability leads to a characteristic gait with dynamic varus deformity, «varus thrust». Dial test is one of the most important in the clinical examination of patients with damage to the posterolateral structures of the knee joint. Anterior and posterior drawer tests, anterior and posterior Lachman tests, front and reverse pivot shift, varus stress test for bending angle in the knee joint from 20° to 30° were performed. Radiography of the knee joint in standard projections (anterior-posterior and lateral) was carried out to exclude concomitant bone injuries. Stress radiography of the knee joint (Fig. 2) is an important point in the diagnosis of lesions of the knee and the structures of the posterolateral angle. In particular, it has been proven that in order to diagnose posterolateral instability, it is necessary to perform stress radiography of the knee joint with varus load at a bending angle of 20° [20]. Magnetic resonance imaging (MRI) was

Table 1

Distribution of patients depending on the damaged structures of the knee joint

Patient group	Type of impairment according to Fanelli–Larson classification [15]				Total
	A, isolated	B, isolated	B, in combination with anterior cruciate ligament damage	C, with posterior cruciate ligament damage	
Study	3	—	8	13	26
Comparison	1	1	12	18	32
Total	4	1	20	33	58

performed on all patients to diagnose concomitant damage to intra-articular structures.

Surgical techniques

The comparison group consisted of patients operated by the LaPrade method (Figs. 3, 4) using a two-bundle autograft, which allowed to restore the biomechanical vector of lig. popliteofibulare, m. popliteus tendon and lig. collaterale fibulare. An end button plate was used to fix the graft in the tibia (Fig. 4). Excessive rotation inward can cause knee contractures. This operation is technically complex, but allows to get good results.

Minimally invasive repair of the posterolateral angle structures

The operation was performed under arthroscopic control. The external meniscus and popliteal tendons were visualized. A feature of damage to the structures of the posterolateral angle was the unimpeded wide opening of the lateral joint space during arthroscopy (Fig. 5).

Therefore, we easily got the arthroscope and coagulator electrode under the external meniscus in the projection of the popliteal tendon, dissected the scars and capsule of the joint 2–3 cm down so that the probe of the tibial conductor could be inserted (Fig. 6). After that, with the FlipCutter 7.0 mm tool, a canal was drilled in the external condyle of the tibia, a guide thread was inserted into it, which was output to the skin through an additional incision in the projection of the graft attachment in the external femur condyle. A graft was removed from the threads, and a button clamp was placed at the distal end. The other end of the graft was passed subcutaneously to the head of the tibia and fixed there with either a tenodesis screw or a 5.5 mm Swivel Lock anchor. The transplant loop was performed subcutaneously to the point of fixation of the patellar tendon on the external femoral condyle, where the canal was drilled, the transplant loop was removed and fixed with an interfering screw, or tied to a plate mounted on the opposite surface of the femur (Fig. 6).

Evaluation of treatment results

Comparative analysis of recovery was performed by assessing the pain syndrome according to VAS. We studied the time course of recovery of movement in the knee joint after surgery and conducted a survey for subjective assessment of overall satisfaction with the results of treatment one year after surgery.

Results and discussion

The results of treatment of patients with damage to the structures of the posterolateral angle were analyzed in both groups. Recurrences of instability were not detected in any case.

In the early postoperative period, the results of treatment of patients concerning the time course of pain (VAS) and recovery of range of motion were evaluated. However, the assessment of range of motion was initially heterogeneous, as the protocols for mobilization of the knee joint after ACL and PCL repair are different. Therefore, we analyzed them separately.

The results by VAS are given in Table 2. Despite the heterogeneity of surgical interventions in the groups, the study showed that with open restoration of the structures of the posterolateral angle, the level of pain by VAS was statistically significantly higher from the first day of the postoperative period, compared with minimally invasive method. The difference remained clinically significant for the first four weeks after surgery, whereas no significant difference in pain between groups was identified in the follow-up.

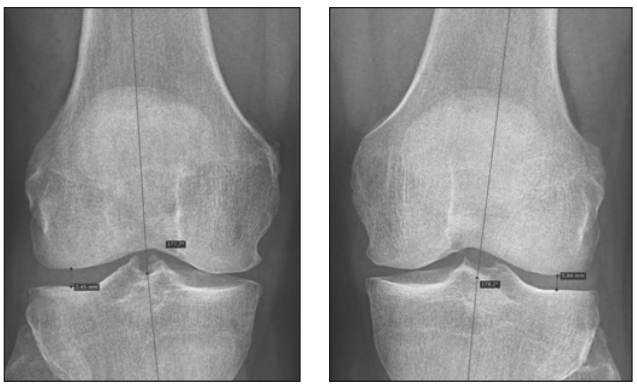

Fig. 2. Radiography of the knee joints with varus stress. Pathological opening of the lateral part of the right knee joint

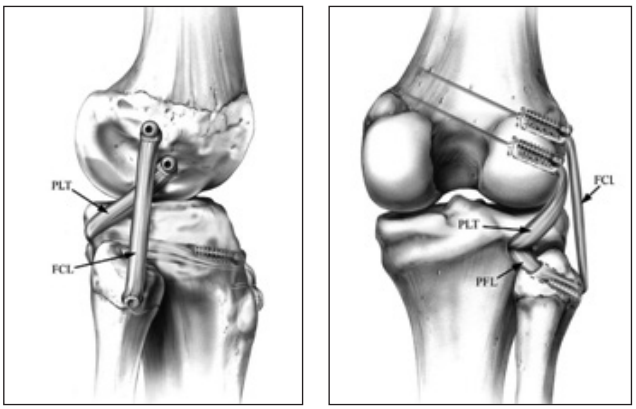

Fig. 3. Reconstruction of the posterolateral angle by LaPrade. View from the lateral side and back. FCL — the bundle reconstructing the bypass tibial ligament, PLT — popliteal tendon, PFL — popliteal-fibular ligament [5, 14]

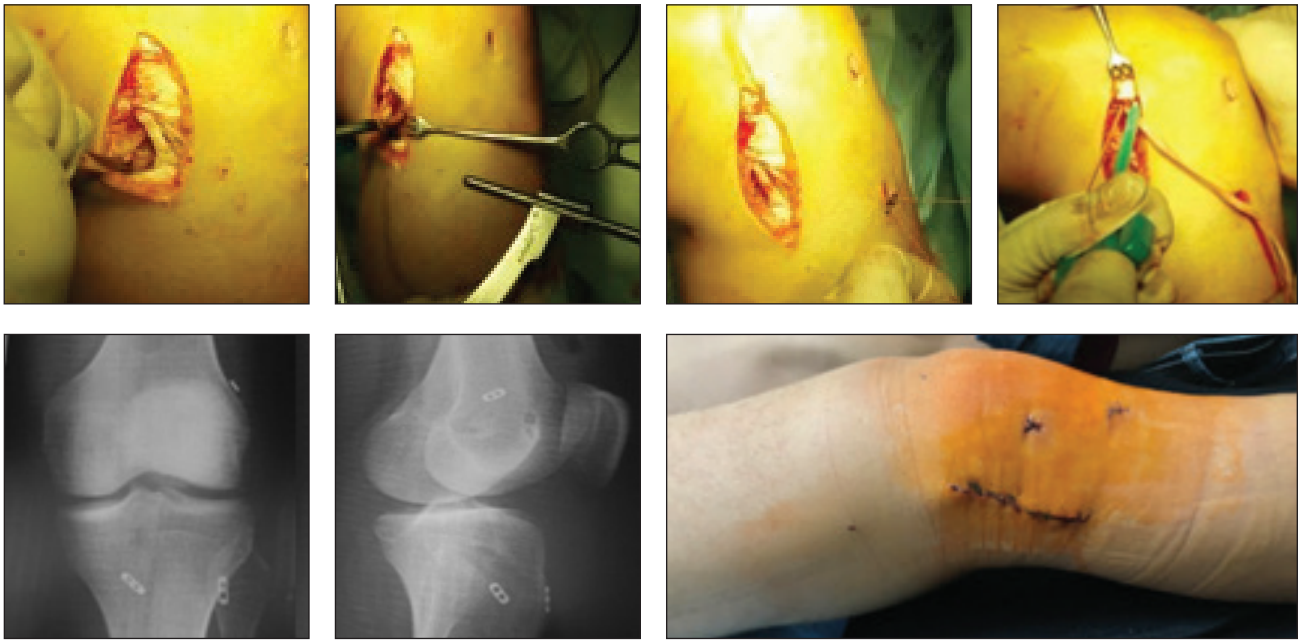

Fig. 4. A clinical example of posterolateral angle repair in simultaneous damage to the ACL. Semi-tendon tendon graft for ACL (all inside technique) and thin muscle tendon graft for posterolateral angle repair

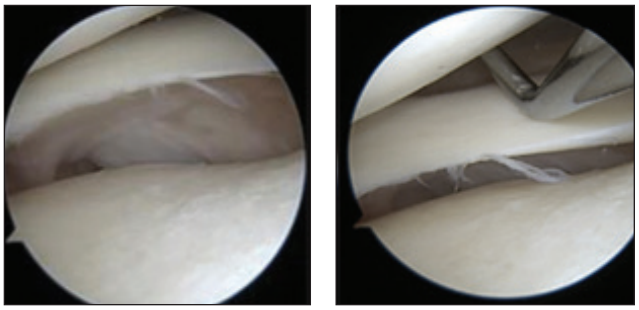

Fig. 5. Opening of the lateral joint space in damage to the posterolateral angle structures

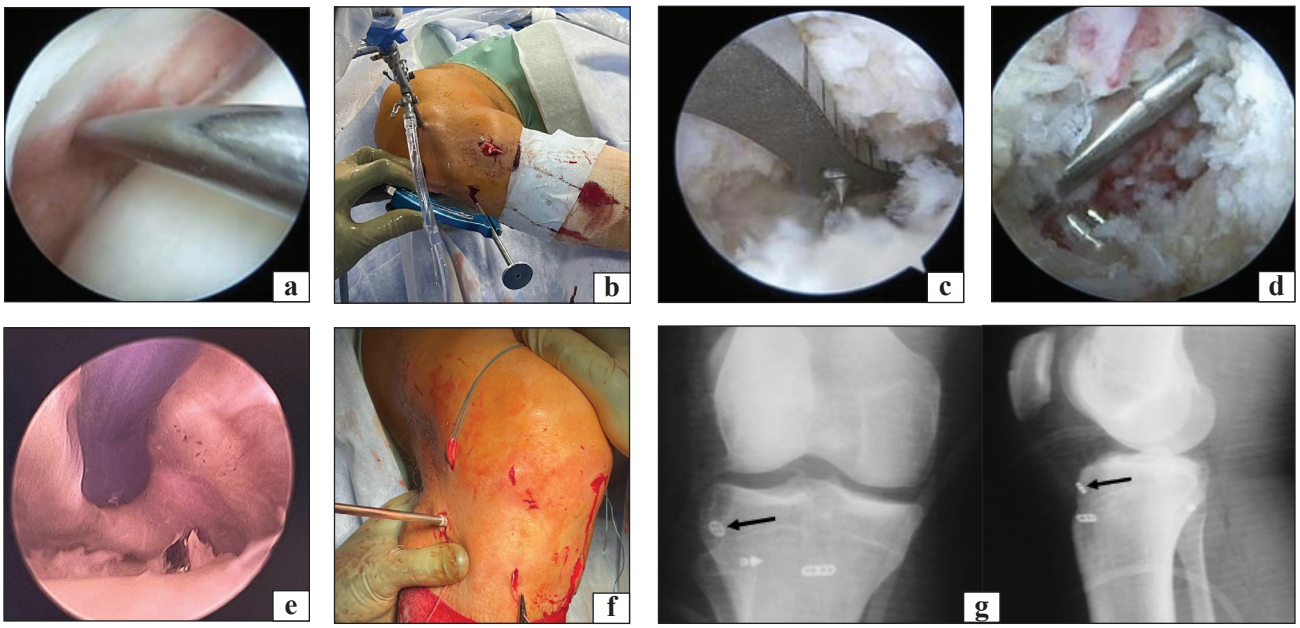

Fig. 6. Stages of endoscopic reconstruction of the popliteal tendon in a patient with ACL injury: a) diagnostic probe under the external meniscus; b, c) installation of the conductor; d) drilling PlipCutter 7.0 mm channel; e) removal of the conductor; f) installation of the graft g) postoperative radiography, the arrow shows the graft fixator

Table 2

Time course of VAS pain syndrome in groups of patients after reconstruction of posterolateral angle structures

Patient group	VAS indicator					
	1st day	2nd day	1st week	4th week	6th week	8th week
Study (endoscopic plastic surgery)	3.1 ± 0.8	2.6 ± 0.6	1.4 ± 0.8	1.2 ± 0.7	1.3 ± 0.9	1.2 ± 1.1
Comparison (open repair)	5.8 ± 0.7	3.6 ± 0.8	2.9 ± 0.6	2.6 ± 1.1	1.4 ± 0.9	1.1 ± 1.0
Statistical significance	$p < 0.01$	$p < 0.01$	$p < 0.05$	$p < 0.05$	$p > 0.05$	$p > 0.05$

Table 3

Range of movements (degree) after restoration of ACL and posterolateral angle structures of a knee joint

Patient group	The range of flexion / extension movements			
	1st week	2nd week	4th week	6th week
Study (endoscopic plastic surgery)	88 ± 11/0	96 ± 7/0	114 ± 9/0	124 ± 11/0
Comparison (open repair)	59 ± 12/0	61 ± 13/0	97 ± 12/0	101 ± 14/0
Statistical significance	$p < 0.01$	$p < 0.05$	$p < 0.05$	$p > 0.05$

Table 4

Range of movements (degree) after restoration of PCL and posterolateral angle structures of a knee joint

Patient group	The range of flexion / extension movements			
	2nd week	4th week	6th week	8th week
Study (endoscopic plastic surgery)	76 ± 10/0	92 ± 11/0	111 ± 9/0	121 ± 18/0
Comparison (open repair)	56 ± 10/0	65 ± 14/0	96 ± 16/0	109 ± 24/0
Statistical significance	$p < 0.01$	$p < 0.05$	$p < 0.05$	$p > 0.05$

The time course of recovery of range of motion (Tables 3, 4) was analyzed separately among patients with reconstruction of anterior and posterior cruciate ligaments. After the reconstruction of the PCL, we always performed a longer immobilization using the PTS splint for 4 weeks and only after 2 weeks proceeded with passive flexion in the knee joint.

The results of the evaluation of the recovery of range of motion indicated a clear trend of rapid recovery among patients with minimally invasive plastic surgery and endoscopic reconstruction of the patellar tendon. In both groups of patients, both in the case of ACL plastic surgery and PCL reconstruction, minimally invasive technique allowed to restore flexion in the knee joint faster by at least 4 weeks.

Subjective assessment of satisfaction with the outcome of the operation after 2 years showed that in the study group 14 (53.85 %) patients were very satisfied, 7 (26.92 %) were satisfied, 5 (19.23 %) were partially satisfied. In the comparison group 16 (50.00 %) individuals were very satisfied, 9 patients (28.13 %) were satisfied, 5 (15.62 %) were partially satisfied, 2 patients (6.25 %) were dissatisfied. Regarding the opinion of patients whether they would agree to identical surgery, understanding the course of the intervention and the postoperative period, the outcome of treatment, it was determined that 54 (93.1 %) of 58 patients would consider having surgery again: 25 (96.1 %) among 26 respondents in the study group, 29 (90.6 %) among 32 from the comparison group.

The results of clinical tests are given in Tables 5, 6. Stability of the knee joint was evaluated by their results. Dial test was used to analyze rotational stability, and varus stress test was used for frontal stability. Similar indicators were obtained in the groups with the best trend in the study group. Due to the small number of patients, we cannot make a proper statistical comparison, as in both groups we performed both isolated reconstruction of the structures of the posterolateral angle and anterior or posterior cruciate ligaments, which implies completely different expectations about the outcome of treatment.

Discussion

Only 4 patients out of 58 were operated on for isolated damage to the structures of the posterolateral angle of the knee joint, which amounted to 7 % and was fully consistent with the literature. Such injuries are not always diagnosed in time due to the fact that they are rare and have a vague presentation in the form of pain in the outer knee joint under conditions of heavy physical activity, such as kick running and

Table 5

Dial-test results in patient groups in the time course

Range of shin rotation		Before operation				After operation			
		0+	1+	2+	3+	0+	1+	2+	3+
Study group, n = 26	abs.	0	9	17	0	21	5	0	0
	%	0.0	34.6	65.4	0.0	80.8	19.2	0.0	0.0
Comparison group, n = 32	abs.	0	11	21	0	20	12	0	0
	%	0.00	34.37	65.63	0.00	62.50	37.50	0.00	0.00

Table 6

Varus stress test results in patient groups in the time course

Range of shin rotation		Before operation ї				After operation			
		0+	1+	2+	3+	0+	1+	2+	3+
Study group, n =26	abs.	2	16	6	2	22	4	0	0
	%	7.69	61.54	23.08	7.69	84.62	15.38	0.00	0.00
Comparison group, n =32	abs.	0	18	14	0	21	8	3	0
	%	0.00	56.25	43.75	0.00	65.62	25.00	9.38	0.00

Table 7

Classification of injuries of the posterolateral structures of a knee joint by Fanelli-Larson [15]

Injury type	Description	Injured structure
A	Increase in external rotation of a shin by 10°	*Lig. popliteofibulare*, *m.popliteus* tendon
B	Increase in external rotation of a shin by 10°. Opening of the lateral part of the knee joint in varus stress test by 5–10 mm	*Lig. popliteofibulare*, *m.popliteus* tendon. *Lig. collaterale fibulare*
C	Increase in external rotation of a shin by 10°. Opening of the lateral part of the knee joint in varus stress test more than 10 mm	*Lig. popliteofibulare*, *m.popliteus* tendon. *Lig. collaterale fibulare*, capsule joint, PCL

changing direction. At the same time MRI showed degenerative changes in the body of the external meniscus, which can later lead to its incomplete rupture. When deciding to stregthen the posterolateral angle, we must remember that this is a very traumatic operation using an auto- or allograft. The use of allografts is more appropriate because it reduces limb injuries, the time of surgery, which is especially important in the treatment of complex injuries of the ligaments.

At the same time, we noted a drawback of G. C. Fanelli and R. V. Larson classification [15], designed to assess cases of posterolateral instability. However, in practice we see patients with ACL injuries, external meniscus and structures of the posterolateral angle of the knee joint. Therefore, Fanelli C damage can be considered as a combination of failure of the structures of the posterolateral angle with the rupture of one of the crossed ligaments, or distinguish 2 types of Fanelli B damage, which are already done by other authors [24].

In our opinion, when treating patients with ACL and PCL ruptures, special attention should be paid to subjects with damage to the posterolateral structures of the knee joint, which have marginal rotational and varus instability: increased external rotation of the tibia about 5° and opening the lateral knee joint for varus stress test up to 5 mm. That is, these indicators are actually clinically possible to record when specifically aimed at. During the dial-test, this can be assessed as a slight tendency to external rotation: slightly more compared to the healthy side. Such cases occur in the case of ruptures of both ACL and PCL. Often we see a slight tendency to external rotation, but restore the isolated damaged central stabilizer of the knee joint (ACL or PCL). Intraoperatively, we additionally check the rotation tests after implant placement and fixation. If the tendency to external rotation persists, it is necessary to repair the structures of the posterolateral angle of the knee joint. There are no ready-made solutions for this yet. If we do not eliminate the pathological rotational component of instability, there will be an overload of the external meniscus and the cross-ligament graft.

PCL reconstruction does not cause great discussion about the routine repair of the structures of the posterolateral angle of the knee joint. In ACL damage, slight external rotation of the tibia is not clearly described as an indication for plastic surgery. Another problem with the reconstruction of the structures of the posterolateral angle is that the repair of the popliteal muscle with a rigid ligament does not allow to fully restore its function. However, due to the lack of better methods, it is necessary to use this approach in clinical practice. It should also be noted that plastic surgery of the posterolateral angle structures cannot accurately reproduce their anatomical setting, and restores only the basic ones.

The appearance in the arsenal of an orthopedist-traumatologist of endoscopic minimally invasive techniques of popliteal tendon plastic surgery under arthroscopic control has reduced the trauma of this surgery and facilitated postoperative rehabilitation.

The disadvantage of our study is the small number of patients, which can be explained by the rare occurrence of such injuries. However, statistical analysis showed significant differences in a number of indicators of the time course of recovery in the study and comparison groups and confirmed a reduction in the trauma of surgery without deterioration of long-term treatment outcomes.

Conclusions

The proposed method of minimally invasive restoration of the posterior lateral angle of the knee joint with arthroscopic reconstruction of the popliteal tendon showed positive immediate and long-term results of treatment of patients, did not lead to increased complications and deterioration of limb function, reduced pain after surgery and joints.

Conflict of interest. The authors declare no conflict of interest.

References

1. Comparative analysis of the results of reconstruction of the posterior cruciate ligament using the «inlay» techniques and transtibial canal conduction / M. L. Golovakha, I. V. Didenko, V. Orlyansky, K. P. Benedetto // Orthopedics, traumatology and prosthetics. — 2019. — № 1. — P. 64–71. — DOI: 10.15674/0030-59872019164-71.
2. Golovakha M. L. Posterior cruciate ligament injuries / M. L. Golovakha, V. Orlyansky, K. P. Benedetto. — Zaporozhye : Prosvita, 2017. — 92 p.
3. Posterolateral corner of the knee: current concepts / J. Chahla, G. Moatshe, C. S. Dean, R. F. LaPrade // The Archives of Bone and Joint Surgery. — 2016. — Vol. 4 (2). — P. 97–103.
4. Gollehon D. L. The role of the posterolateral and cruciate ligaments in the stability of the human knee. A biomechanical study / D. L. Gollehon, P. A. Torzilli, R. F. Warren // The Journal of Bone and Joint Surgery. American volume. — 1987. — Vol. 69 (2). — P. 233–242.
5. The posterolateral attachments of the knee: a qualitative and quantitative morphologic analysis of the fibular collateral ligament, popliteus tendon, popliteofibular ligament, and lateral gastrocnemius tendon / R. F. LaPrade, T. V. Ly, F. A. Wentorf, L. Engebretsen // The American Journal of Sports Medicine. — 2003. — Vol. 31 (6). — P. 854–860. — DOI: 10.1177/03635465030310062101.
6. Posterolateral corner of the knee: an expert consensus statement on diagnosis, classification, treatment, and rehabilitation / J. Chahla, I. R. Murray, J. Robinson [et al.] // Knee Surgery, Sports Traumatology, Arthroscopy. — 2019. — Vol. 27 (8). — P. 2520–2529. — DOI: 10.1007/s00167-018-5260-4.
7. Posterior laxity increases over time after PCL reconstruction / C. Gwinner, T. M. Jung, I. Schatka, A. Weiler // Knee Surgery, Sports Traumatology, Arthroscopy. — 2019. — Vol. 27 (2). — P. 389–396. — DOI: 10.1007/s00167-018-5035-y.
8. Evolving evidence in the treatment of primary and recurrent posterior cruciate ligament injuries, part 2: surgical techniques, outcomes and rehabilitation / P. W. Winkler, B. Zsidai, N. N. Wagala [et al.] // Knee Surgery, Sports Traumatology, Arthroscopy. — 2021. — Vol. 29 (3). — P. 682–693. — DOI: 10.1007/s00167-020-06337-2.
9. Minimally invasive, arthroscopic-assisted, anatomic posterolateral corner reconstruction / K. Hermanowicz, K. Malinowski, A. Goralczyk [et al.] // Arthroscopy Techniques. — 2019. — Vol. 8 (3). — P. e251–e257. — DOI: 10.1016/j.eats.2018.10.021.
10. Wood R. Anatomic posterolateral corner reconstruction using single graft plus adjustable-loop suspensory fixation device / R. Wood, J. Robinson, A. Getgood // Arthroscopy Techniques. — 2019. — Vol. 8 (3). — P. e301–e309. — DOI: 10.1016/j.eats.2018.11.011.
11. Fibular collateral ligament/ posterolateral corner injury: when to repair, reconstruct, or both / M. I. Kennedy, A. Bernhardson, G. Moatshe [et al.] // Clinics in Sports Medicine. — 2019. — Vol. 38 (2). — P. 261–274. — DOI: 10.1016/j.csm.2018.11.002.
12. The use of allograft tissue in posterior cruciate, collateral and multiligament knee reconstruction / M. J. Strauss, R. Varatojo, T. Boutefnouchet [et al.] // Knee Surgery, Sports Traumatology, Arthroscopy. — 2019. — Vol. 27 (6). — P. 1791–1809. — DOI: 10.1007/s00167-019-05426-1.
13. Anatomic reconstruction of the posterolateral corner: an all-arthroscopic technique / J. Frings, J. P. Kolb, T. C. Drenck [et al.] // Arthroscopy Techniques. — 2019. — Vol. 8 (9). — P. e999–e1006. — DOI: 10.1016/j.eats.2019.05.010.
14. Arthroscopic reconstruction of the popliteus complex: accuracy and reproducibility of a new surgical technique / K. H. Frosch, R. Akoto, M. Heitmann [et al.] // Knee Surgery, Sports Traumatology, Arthroscopy. — 2015. — Vol. 23 (10). — P. 3114–3120. — DOI: 10.1007/s00167-014-3000-y.
15. Fanelli G. C. Practical management of posterolateral instability of the knee / G. C. Fanelli, R. V. Larson // Arthroscopy. — 2002. — Vol. 18 (2 Suppl 1). — P. 1–8. doi: 10.1053/jars.2002.31779.
16. Posterior cruciate ligament injuries: what do we really know? / P. W. Winkler, J. D. Hughes, J. J. Irrgang [et al.] // Knee Surgery, Sports Traumatology, Arthroscopy. — 2021. — Vol. 29 (3). — P. 669–671. — DOI: 10.1007/s00167-020-06425-3.
17. Anatomy; Journal of bone & joint surgery: http: //www.boneandjoint
18. An analysis of an anatomical posterolateral knee reconstruction: an *in vitro* biomechanical study and development of a surgical technique / R. F. LaPrade, S. Johansen, F. A. Wentorf [et al.] // The American journal of sports medicine. — 2004. — Vol. 32 (6). — P. 1405–1414. — doi: 10.1177/0363546503262687.
19. Evolving evidence in the treatment of primary and recurrent posterior cruciate ligament injuries, part 1: anatomy, biomechanics and diagnostics / P. W. Winkler, B. Zsidai, N. N. Wagala [et al.] // Knee Surgery, Sports Traumatology, Arthroscopy. —

2021. — Vol. 29 (3). — P. 672–681. — DOI: 10.1007/s00167-020-06357-y.
20. A hamstring-based anatomic posterolateral knee reconstruction with autografts improves both radiographic instability and functional outcomes / C. E. Franciozi, L. J. B. Albertoni, M. S. Kubota [et al.] // Arthroscopy. — 2019. — Vol. 35 (6). — DOI: 10.1016/j.arthro.2019.01.016.
21. An all-arthroscopic technique for complex posterolateral corner reconstruction / J. P. Kolb, J. Frings, M. Krause [et al.] // Arthroscopy techniques. — 2019. — Vol. 8 (9). — P. e999–e1006. — DOI: 10.1016/j.eats.2019.05.010.
22. The reproducibility and repeatability of varus stress radiographs in the assessment of isolated fibular collateral ligament and grade-III posterolateral knee injuries: an *in vitro* biomechanical study / R. F. LaPrade, C. Heikes, A. J. Bakker, R. B. Jakobsen // The Journal of Bone and Joint Surgery. American volume. — 2008. —Vol. 90 (10). — P. 2069–2076. — DOI: 10.2106/JBJS.G.00979.
23. Outcomes of an anatomic posterolateral knee reconstruction / R. F. LaPrade, S. Johansen, J. Agel // The Journal of Bone and Joint Surgery. American volume. — 2010. — Vol. 92. — P. 16–22. — DOI:10.2106/JBJS.I.00474.
24. The Posterolateral Instability Score (PoLIS) of the knee joint: a guideline for standardized documentation, classification, and surgical decision-making / A. Weiler, K. H. Frosch, C. Gwinner [et al.] // Knee Surgery, Sports Traumatology, Arthroscopy. — 2021. — Vol. 29 (3). — P. 889–899. — DOI: 10.1007/s00167-020-06044-y.

The article has been sent to the editors 10.10.2021

RESULTS OF MINIMALLY INVASIVE KNEE POSTEROLATERAL CORNER RECONSTRUCTION

M. L. Golovakha [1], S. A. Bondarenko [2], W. Orljanski [3]

[1] Zaporizhzhia State Medical University. Ukraine
[2] «Motor Sich» Clinic, Zaporizhzhia. Ukraine
[3] Vienna Private Clinic. Austria

✉ Maxim Golovakha, MD, Prof. in Traumatology and Orthopaedics: golovahaml@gmail.com
✉ Stanislav Bondarenko, MD: trauma.bon.s@gmail.com
✉ Weniamin Orljanski, MD, Prof. in Traumatology and Orthopaedics: orljanski@hotmail.com