KNEE JOINT CONDITION AND QUADRICEPS FUNCTION IN PATIENTS AFTER MENISCECTOMY: CLINICAL, FUNCTIONAL, AND MORPHOLOGICAL ANALYSIS

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Abstract. This article presents the results of a comprehensive study of knee joint condition and quadriceps function in patients after meniscectomy using clinical, functional, and instrumental methods. We analyzed the relationships between pain levels, muscle strength, range of motion, functional status, and morphological changes in articular cartilage based on MRI data. The study included 164 patients after partial or complete meniscectomy and 68 healthy volunteers in the control group. The results showed that pain severity, decreased quadriceps strength, and limited motion are closely related to articular cartilage condition and baseline anthropometric characteristics. The identified patterns allow the development of personalized medical rehabilitation programs aimed at restoring muscle function, reducing pain, and preventing degenerative changes after surgery.

Key words: meniscectomy, knee joint, quadriceps, pain, muscle strength, functional status, MRI, rehabilitation, Lysholm, VAS.

Relevance. Meniscectomy remains one of the most common orthopedic surgeries used for meniscus injuries in the knee joint [1, 2]. Despite the introduction of modern arthroscopic and organ-preserving techniques, complete restoration of the knee joint's biomechanical balance after meniscus removal is not always achieved. Even partial meniscectomy leads to increased contact pressure on the articular surfaces, impaired load distribution, and accelerated wear of the articular cartilage [3]. These changes contribute to the development of degenerative processes, including post-traumatic osteoarthritis, which significantly limits the patient's functional capabilities.

One of the key consequences of the surgery is severe weakness of the quadriceps femoris, caused not only by pain and forced physical inactivity, but also by neuromuscular dysfunction resulting from changes in proprioceptive regulation after meniscus removal [4]. Weakness of the quadriceps reduces knee joint stability, limits range of motion, and slows the process of restoring motor activity, especially in individuals leading an active lifestyle and participating in sports.

At the same time, the complex relationship between clinical manifestations (pain, functional limitations), objective functional indicators (muscle strength, range of motion), and structural changes in the joint (according to MRI data) in patients after meniscectomy remains insufficiently studied [5]. The lack of such studies complicates the personalization of rehabilitation programs and the prediction of surgical outcomes.

Thus, a comprehensive study of clinical, functional and morphological characteristics in patients after meniscectomy is important for the development of effective medical rehabilitation strategies aimed at restoring muscle strength, optimizing knee joint biomechanics and preventing degenerative complications.

The aim of the study was to determine the relationship between clinical, functional, and morphological parameters in patients after meniscectomy to support personalized approaches to medical rehabilitation.

Materials and Methods. The study included 164 patients aged 18 to 60 years who had undergone partial or complete removal of the knee meniscus (meniscectomy). Partial meniscectomy was performed in 104 patients, and complete meniscectomy was performed in 60. The control group consisted of 68 apparently healthy volunteers, matched for age and gender to the main sample (Table 1).

Table 1.

Average anthropometric and clinical parameters of the examined patients

Indicator	(SD)
Age, years	34.8 ± 8.7
Body mass index, kg/m²	25.0 ± 3.0

Note: Data are presented as mean ± standard deviation (SD) calculated for the entire patient sample (n = 164).

To comprehensively assess the condition of the knee joint and the effectiveness of the recovery process, a clinical, functional, and instrumental examination was performed. Pain intensity was measured using a visual analog scale (VAS), and knee joint function was assessed using the Lysholm scale, which characterizes the degree of limitation in daily and physical activity. Range of motion in the joint was measured using goniometry, and quadriceps strength was assessed using a handheld dynamometer.

In addition, magnetic resonance imaging (MRI) was performed in 64 patients to identify morphological changes in articular cartilage and assess the condition of the residual meniscus and ligamentous apparatus.

Exclusion criteria were: the presence of injuries or surgeries on the contralateral knee joint, inflammatory diseases of the musculoskeletal system, as well as contraindications to magnetic resonance imaging.

Statistical processing of the obtained data was performed using the Statistical Package for the Social Sciences (SPSS) software, version 23.0. The Student's t-test and Mann–Whitney U-test were used to analyze differences between groups. Relationships between indicators were determined using correlation analysis with a statistical significance level of $p < 0.05$.

Results.

Table 2.

Distribution of examined patients by gender, type of injury and affected meniscus

Indicator	Category	n	%
Total number of patients		164	100
Floor	Men	102	62.2
	Women	62	37.8
Mechanism of injury	Sports	74	45.1
	Domestic	56	34.1
	Degenerative	34	20.8
Damaged meniscus	Medial	99	60.4
	Lateral	65	39.6

Note: Percentages are calculated from the total number of patients (n = 164).

Table 2 shows the distribution of patients (n = 164) by gender, mechanism

of injury, and type of affected meniscus. Men predominated among the examined patients — 62.2% (n = 102), reflecting a higher injury rate in individuals leading an active lifestyle and playing sports. Women accounted for 37.8% (n = 62). The most common cause of meniscus injury was sports injury — 45.1% of cases (n = 74), which is consistent with the literature data on high loads on the knee joint during team and contact sports. Domestic injuries were observed in 34.1% of patients (n = 56), and degenerative changes in 20.8% (n = 34), mainly in individuals over 40 years of age. The medial meniscus was most often affected — in 60.4% of patients (n = 99), which is explained by its lesser mobility and greater susceptibility to axial loads. The lateral meniscus was damaged in 39.6% (n = 65).

The majority of patients undergoing meniscectomy are working-age men who sustained a sports injury, primarily affecting the medial meniscus. These data support the need to develop preventative and rehabilitation programs targeted at active populations, particularly athletes and individuals with increased physical activity.

Table 3.

Average anthropometric and clinical parameters of the examined patients (n = 164)

Indicator	**Mean ± standard deviation (SD)**
Age, years	34.8 ± 8.7
Body mass index, kg/m²	25.0 ± 3.0
Duration of the postoperative period, months	7.4 ± 2.6
Range of motion in the knee joint, °	118.6 ± 8.3
Pain intensity on the visual analogue scale (VAS), points	4.8 ± 1.2
Functional status according to the Lysholm scale, points	78.4 ± 6.5
Quadriceps strength (according to dynamometry data), kg	26.8 ± 5.4
Articular cartilage condition (MRI assessment, Outerbridge score)*	2.1 ± 0.8

Note: The Outerbridge cartilage score was assessed in 64 patients who underwent magnetic resonance imaging (MRI).

Table 3 presents the average anthropometric and clinical parameters of 164 patients after meniscectomy. The average age of the subjects was 34.8 ± 8.7 years, corresponding to the most active working age, when the risk of sports and household injuries is particularly high. The average body mass index was 25.0 ± 3.0 kg/m²,

indicating a tendency toward moderate excess body weight, which can increase stress on the knee joint and delay recovery.

The average postoperative follow-up period at the time of examination was 7.4 ± 2.6 months, allowing for an assessment of both the early and mid-term effects of the procedure. Knee range of motion was reduced to 118.6 ± 8.3°, reflecting a moderate contracture compared to the physiological norm (approximately 135°).

The visual analog scale (VAS) pain intensity was 4.8 ± 1.2 points, indicating persistent pain. The mean Lysholm functional scale score was 78.4 ± 6.5, indicating moderate functional limitation after surgery.

Quadriceps strength, measured with a handheld dynamometer, was 26.8 ± 5.4 kg, which is below the age norm and confirms muscle weakness. The mean Outerbridge score, which characterizes the condition of articular cartilage based on magnetic resonance imaging (MRI), was 2.1 ± 0.8, consistent with moderate degenerative changes (cartilage softening and initial defects).

The results of an analysis of average parameters demonstrate that after meniscectomy, most patients continue to experience signs of functional impairment, pain, and moderate degenerative changes in the articular cartilage. These data support the need for comprehensive and long-term medical rehabilitation aimed at restoring quadriceps strength, optimizing joint mobility, and preventing the progression of postmeniscectomy osteoarthritis.

Table 4.

Clinical and functional indicators

Indicator	**After meniscectomy (n = 164)**	**Control (n = 68)**	***p***
Pain according to VAS, points	4.8 ± 1.2	0.8 ± 0.6	< 0.01
Lysholm scale, points	78.4 ± 6.5	95.2 ± 3.1	< 0.01
Range of motion, °	118.6 ± 8.3	135.4 ± 4.7	< 0.01
Quadriceps strength, % of normal	75.5 ± 6.1	100	< 0.01

Table 4 presents a comparison of clinical and functional parameters in patients after meniscectomy and in a control group of apparently healthy individuals. The analysis revealed that patients after surgery retained significant deviations in all parameters studied.

The pain intensity according to the visual analog scale (VAS) in the operated patients was 4.8 ± 1.2 points, which is significantly higher than in the control group (0.8 ± 0.6 points, $p < 0.01$), reflecting the presence of persistent pain syndrome.

The average Lysholm functional scale score in the study group was 78.4 ± 6.5, while in healthy participants it was 95.2 ± 3.1 ($p < 0.01$). This indicates a significant decrease in the functional capacity of the knee joint after meniscectomy.

The range of motion in patients after surgery was 118.6 ± 8.3°, which is significantly less than in healthy individuals (135.4 ± 4.7°, $p < 0.01$), indicating moderate limitation of mobility and the formation of contracture syndrome.

Quadriceps strength in postoperative patients decreased to 75.5 ± 6.1% of the age-appropriate norm, compared to 100% in the control group ($p < 0.01$). This reflects muscle wasting and functional weakness characteristic of the postoperative period.

The analysis results demonstrate that after meniscectomy, patients experience persistent pain, decreased quadriceps strength, limited joint mobility, and deterioration in functional status. These differences are significant compared to the control group and highlight the need for individualized rehabilitation programs aimed at restoring muscle strength, increasing range of motion, and reducing pain to prevent the development of postmeniscectomy osteoarthritis.

Table 5.

Morphological data on MRI

Indicator	**Main group (n = 64)**	**Control (n = 40)**	***p***
Condition of articular cartilage (normal/changes)	38 (59.4%) / 26 (40.6%)	40 (100%) / 0	< 0.01
Residual meniscus (preserved/partially removed)	45 (70.3%) / 19 (29.7%)	—	—
Ligamentous apparatus (norm / changes)	57 (89.1%) / 7 (10.9%)	40 (100%) / 0	0.05

Table 5 presents the morphological data obtained by magnetic resonance imaging (MRI) in patients after meniscectomy (the study group) and in healthy individuals (the control group). In the majority of patients after meniscectomy (59.4%), the condition of the articular cartilage remained close to normal; however,

40.6% showed varying degrees of degenerative changes, including thinning, signal unevenness, and signs of chondromalacia. In the control group, all subjects (100%) had normal articular cartilage ($p < 0.01$), confirming the impact of surgical intervention on the morphological integrity of cartilage tissue.

Regarding meniscal condition, 70.3% of patients demonstrated partial meniscal preservation, while 29.7% had significant meniscal removal. This ratio reflects the prevalence of organ-preserving procedures, but also highlights that nearly a third of patients underwent more extensive resection, increasing the risk of postmeniscectomy changes.

Regarding the condition of the ligamentous apparatus in the study group, 89.1% of subjects had intact structures, while 10.9% had secondary changes—thickening, swelling, or partial tears. In the control group, all parameters were within normal limits ($p = 0.05$).

Morphological MRI data indicate that even with partial meniscectomy, there remains a risk of structural changes in the articular cartilage and ligamentous components. In 40% of patients, signs of degenerative changes develop in the early postoperative period, confirming the need for early rehabilitation measures aimed at restoring the biomechanical balance of the knee joint and preventing chondropathy and secondary musculoskeletal disorders .

Table 6.

Correlation relationships

Indicators	***r***	***p***
YOUR ↔ quadriceps strength	-0.62	< 0.01
Lysholm ↔ range of motion	0.68	< 0.01
Quadriceps strength ↔ cartilage condition (MRI)	0.55	< 0.01
YOUR ↔ Cartilage Condition (MRI)	-0.58	< 0.01
Lysholm ↔ quadriceps strength	0.61	< 0.01

Table 6 presents the results of a correlation analysis reflecting the relationships between clinical, functional, and morphological parameters in patients after meniscectomy. A negative correlation was observed between pain intensity on the visual analog scale (VAS) and quadriceps strength (r = -0.62; $p < 0.01$), indicating that the more severe the pain, the greater the decrease in muscle strength.

This confirms the significant influence of pain on the recovery of muscle function.

A positive correlation was found between the Lysholm scale score and range of motion ($r = 0.68$; $p < 0.01$), reflecting a direct link between functional status and knee joint mobility. Similarly, a positive association was found between articular cartilage condition as measured by MRI and quadriceps strength ($r = 0.55$; $p < 0.01$), confirming that intact cartilage promotes better functional recovery.

Furthermore, a negative correlation was found between pain levels and cartilage condition ($r = -0.58$; $p < 0.01$), as well as a positive correlation between Lysholm scale scores and quadriceps strength ($r = 0.61$; $p < 0.01$). This suggests that pain reduction and restoration of muscle function directly improve the patient's overall functional status.

The results of the correlation analysis confirm the existence of close relationships between pain, muscle strength, mobility, and the structural condition of the cartilage. The most significant determinants of knee joint function recovery after meniscectomy are pain severity, quadriceps strength, and articular cartilage condition. These data highlight the need for a comprehensive and personalized approach to rehabilitation, including pain management, restoration of muscle tone, and protection of cartilage from degenerative changes.

Discussion The obtained results demonstrate that meniscectomy has a significant and multifaceted impact on the functional state of the knee joint, the biomechanics of movement, and muscle activity of the lower limb. Even partial removal of the meniscus leads to changes in the distribution of intra-articular loads, which increases contact pressure on the articular cartilage, accelerates its wear, and contributes to the development of early degenerative changes.

These processes provoke pain and a reflex decrease in the activity of the quadriceps femoris, which plays a key role in knee stabilization and provides shock absorption during movement. The identified negative correlation between pain intensity and quadriceps strength ($r = -0.62$) reflects a typical manifestation of the "vicious cycle" of rehabilitation: pain limits muscle activity, and decreased strength,

in turn, exacerbates functional instability and increases pain. This emphasizes the importance of early inclusion of methods aimed at activating the hip extensor muscles, gradually increasing their tone, and improving proprioceptive control in the rehabilitation program. Magnetic resonance imaging revealed morphological changes in the cartilage in 40% of patients, corresponding to early stages of degeneration according to the Outerbridge scale. Even with partial preservation of the meniscus, structural changes in the articular surfaces occur, requiring not only therapeutic exercises but also metabolic support for the cartilage tissue. Thus, the data obtained indicate the need for a comprehensive and personalized approach to recovery after meniscectomy. Rehabilitation programs should include pain management using physical therapy and medication, quadriceps activation and strengthening, exercises to restore range of motion and proprioception, as well as measures to prevent articular cartilage overload and provide metabolic tissue support. The use of individualized rehabilitation strategies not only improves functional outcomes but also reduces the risk of postmeniscectomy osteoarthritis, which remains one of the most common late-term problems after meniscal removal.

Conclusions : Patients after meniscectomy demonstrate a significant increase in pain, a decrease in quadriceps strength, and a decrease in functional status according to the Lysholm scale. Morphological changes in articular cartilage were detected in 40% of patients and reliably correlated with clinical and functional disorders. There is a positive relationship between quadriceps strength and cartilage condition ($r = 0.55$; $p < 0.01$), and a negative relationship between pain level and functional indicators ($r = -0.62$; $p < 0.01$). Comprehensive rehabilitation should include early quadriceps strengthening, restoration of range of motion, and pain control to prevent progression of degenerative changes.

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