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Prognostic factors in the treatment of focal osteochondral lesions of the knee and ankle

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Osteochondral lesions of the knee and ankle joints are a common pathology that often results in decreased physical activity and early osteoarthritis. Despite the wide range of available surgical techniques, their efficacy varies considerably. Identifying prognostic factors is essential for optimizing treatment strategies. Studying and taking into account the factors that determine the outcome of treatment is a relevant issue in terms of improving the efficiency of providing care to patients in this category. Objective. To identify prognostic factors and informativeness coefficients in treatment of patients with osteochondral lesions. Methods. A retrospective study included 390 patients with focal osteochondral lesions treated with arthroscopic debridement, microfracture, drilling, or osteochondral autograft transplantation. Treatment effectiveness was evaluated using 21 clinical and morphological parameters and functional scores (Lysholm, AOFAS, SF-36, NRS) at 12–36-month follow-up. Statistical analysis included Bayesian probabilistic methods adapted for clinical research, Kulback's information measure to assess information coefficients, and a heterogeneous sequential procedure based on Wald analysis to determine prognostic coefficients. Results. Positive outcomes were observed in 284 patients (72.8 %), while 106 (27.2 %) had negative outcomes. Key prognostic factors included age, body mass index, lesion size, Kellgren & Lawrence osteoarthritis stage, lesion chronicity, limb axis deviations, and prior surgical history. Conclusions. The identified prognostic and informativeness coefficients have practical value for establishing an individualized approach to selecting the optimal treatment strategy and improving long-term outcomes.

Локальні внутрішньосуглобові кістково-хрящові ушкодження колінного та надп'ятково-гомілкового суглобів є поширеною патологією, що часто призводить до зниження фізичної активності та розвитку остеоартрозу. Незважаючи на великий вибір хірургічних методів, їх ефективність і результативність значно відрізняється. Вивчення та врахування чинників, які детермінують результат лікування є актуальним питанням в аспекті покращення ефективності надання допомоги хворим цієї категорії. Мета. Визначити прогностичні чинники та їхню інформативность у лікуванні пацієнтів із локальними внутрішньосуглобовими кістково-хрящовими ушкодженнями. Методи. Проведено ретроспективне дослідження 390 осіб із локальними кістково-хрящовими травмуваннями, яким застосовували артроскопічний дебридмент, мікрофрактуринг, тунелізацію й остеохондральну аутогенну трансплантацію. Ефективність лікування оцінювали за 21 клініко-морфологічним фактором і функціональними шкалами (Lysholm, AOFAS, SF-36, NRS) у віддаленому періоді (12–36 міс.). Статистичну обробку даних проводили з використанням методів імовірнісного аналізу на основі Байєсових алгоритмів, адаптованих для клінічних досліджень, інформативність окремих клінічних факторів із використанням інформаційної міри Кульбака, а прогностичні коефіцієнти зі застосуванням методики неоднорідної послідовної процедури, яка базується на аналізі Вальда. Результати. Позитивний ефект було досягнуто в 284 (72,8 %) пацієнтів, а негативний — 106 (27,2 %). Виявлено, що найбільш вагомими прогностичними факторами є вік, індекс маси тіла, розмір і давність ушкодження, стадія остеоартрозу за Kellgren & Lawrence, порушення осі кінцівки й хірургічне лікування в анамнезі. Висновки. Визначені прогностичні чинники та коефіцієнти інформативності мають практичну цінність для формування індивідуального підходу до вибору оптимальної тактики лікування та покращення віддалених результатів. Ключові слова. Остеоартроз, колінний суглоб, надп'ятково-гомілковий суглоб, хрящ, реконструктивні операції, лікування.

Keywords. Osteoarthritis, knee, ankle, cartilage, reconstructive surgery, treatment

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Introduction

Local intra-articular bone-cartilage injuries of the knee joint (KJ) and ankle joint (AJ) remain one of the most complex problems in modern orthopedics and traumatology, as articular cartilage has an extremely limited potential for self-repair [1]. Injuries that reach the subchondral bone lead to the progression of osteoarthritis and a significant reduction in the quality of life of the patient and their physical activity [2].

There is a wide range of surgical methods for treating bone-cartilage injuries aimed at stimulating the bone marrow (microfracturing, abrasive chondroplasty, tunneling) [1], fixation of bone-cartilage fragments, and procedures aimed at restoring hyaline cartilage (osteochondral autograft transplantation [3], allografting [4], autologous chondrocyte implantation [5]). Nevertheless, in clinical settings, the most frequently employed techniques are those designed to stimulate the bone marrow and are more affordable.

Published clinical studies confirm that the success of treatment for bone-cartilage injuries does not depend solely on the chosen surgical intervention but requires a multifactorial approach and de pends on a number of prognostic criteria [1, 7]. The obtained regenerate of insufficient quality may lead to further development of degenerative-dystrophic changes [8], or an inadequate assessment of the regenerative potential, even with the use of complex and modern techniques, may result in a negative treatment outcome. This emphasizes the need to determine the prognostic factors for the successful treatment of patients in this group.

Objective: To identify prognostic factors and coefficients of informativeness in the treatment of patients with local intra-articular bone-cartilage injuries.

Materials and Methods

The study involved a retrospective analysis of the treatment outcomes of 390 patients with local intra-articular bone-cartilage injuries of the knee and ankle joints. These patients underwent treatment at the clinical bases of the Department of Traumatology and Orthopedics of O.O. Bohomolets National Medical University in 2022–2024. The study was approved by the bioethics committee of the respective institution (protocol No. 162 dated 31.10.2025) in accordance with the Helsinki Declaration of Human Rights and Biomedicine, as well as the current legislation of Ukraine. All patients signed informed consent.

Inclusion criteria: Age between 18 and 60 years, presence of bone-cartilage injury (requiring treatment and confirmed by instrumental diagnostic methods), application of one of the surgical interventions (debridement with abrasive chondroplasty, microfracturing, tunneling, osteochondral autograft transplantation) or their combination, stage 0–II osteoarthritis according to the Kellgren & Lawrence classification [9], absence of joint instability due to damage to the capsuloligamentous apparatus (except in cases where its restoration is performed in a single stage with the procedure for bone-cartilage injury restoration), availability of complete data for evaluating outcomes before surgery and in the long-term period (12–36 months).

Exclusion criteria: Age under 17 or over 60 years, stage III–IV osteoarthritis according to the Kellgren & Lawrence classification, presence of joint instability due to damage to the capsuloligamentous apparatus, acute infectious process, pregnancy and breastfeeding period, presence of absolute contraindications for surgical treatment.

Among the 390 patients, 238 had knee joint injuries, and 152 had ankle joint injuries.

The treatment outcomes were evaluated using the Lysholm functional scale for the knee joint [10], AOFAS scale for the ankle joint [11], quality of life according to the SF-36 scale [12], and pain level according to the numerical rating scale (NRS) [13]. Rehabilitation protocols were standardized according to the type of intervention. A total of 21 clinical-morphological and anamnesis factors were studied.

Statistical analysis was performed using Microsoft Excel 2019 and StatSoft Statistica 10 software. The forecasting methodology we applied was based on Bayesian probability analysis algorithms. This methodology is adapted and widely tested in clinical practice for predicting various pathological processes [14]. The informativeness of individual factors for predicting treatment outcomes was determined based on the use of the Kullback information measure. After assessing the informational significance of the parameters, prognostic coefficients (PC) of successful treatment depending on individual factors were calculated.

The methodological basis of the study was the use of the heterogeneous sequential procedure, based on Wald's analysis. This methodology calculates the sum of prognostic coefficients for individual clinical parameters and compares the total prognostic coefficient with critical threshold values. At the same time, the same type I error (probability of missing the optimal result group) was set at 5 % ($p < 0.05$), and the type II error (incorrect evaluation of the optimal treatment outcome) was set at no more than 20 % of cases.

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Results

Analysis of the outcomes at the long-term period (12–36 months) showed that a positive effect was achieved in 284 (72.8 %) patients, while an unsatisfactory result was observed in 106 (27.2 %).

At the end of the study, the coefficient of informativeness and prognostic coefficient for each factor were determined in all 390 patients from the retrospective group (see table).

21 clinical-morphological and history factors were studied, which can be categorized as follows:

– Morphological factors: diameter (mm), area (cm^2), volume (cm^3), depth (mm) of the bone-cartilage injury, degree of damage according to ICRS, osteoarthritis stage according to Kellgren & Lawrence.

– Clinical factors: age (groups under or over 40 years), body mass index (BMI) (under or over 30 kg/m^2), presence of axial deformity (varus, valgus, none), joint instability (no, yes), contracture (flexion, extension, combined, none), synovitis, weight-bearing ability (before and after treatment).

– History factors: gender, duration of injury (less than or more than one year), affected joint (knee, ankle), etiology (traumatic, degenerative), conservative and surgical treatment in the medical history.

Factors examined also included damage to the joint structures (medial or lateral meniscus, anterior or posterior cruciate ligament, lateral collateral or medial collateral ligament of the knee joint, lateral and medial ligament groups of the ankle joint) or their absence, history of previous surgical treatment, zones of injury for the knee and ankle joints.

The threshold values of the prognostic coefficients range from –80 to +80. Exceeding the upper threshold (+80) indicates a high likelihood of an optimal treatment outcome. Intermediate prognostic evaluations are as follows: –80 to –50 (group with a low probability of a satisfactory outcome), –49.9 to +20 (group with a medium probability), +20.1 to +80 (group with a high probability). The prognostic procedure involves an overall evaluation of the selected factors inherent to each patient (sum of prognostic coefficients).

Younger age (< 40 years) has a significantly positive impact on treatment outcomes (PC = +7.7), while older patients (> 40 years) tend to show reduced treatment effectiveness (PC = –3.4). However, in addition to age, factors such as current activity level, anticipated future activity, and functional demands should also be taken into account. BMI also significantly impacts treatment results, as patients with a BMI < 30 kg/m^2 have a good prognostic co-

Table

Factors and their prognostic coefficients for predicting treatment outcomes in patients with local intra-articular bone-cartilage injuries

Factor	Subgroup	Prognostic coefficient
1	2	3
Gender	male female	–1.1 2.5
Age	under 40 over 40	7.7 –3.4
BMI	less than 30 more than 30	9.5 –9.0
Injury duration	less than one year more than one year	6.9 –2.5
Joint instability	no yes	–6.1 –7.1
Contracture	no flexion extension combined	6.2 0.0 –10.9 0.0
Affected joint	knee ankle	–0.8 1.3
Deformity	none valgus varus	3.2 –11.7 –6.9
Etiology	degenerative traumatic	–1.8 6.1
Conservative treatment	no yes	5.3 –1.4
Surgical treatment (in medical history)	no yes	9.1 –6.7
Cartilage restoration (in medical history)	Microfracturing Tunnelization Osteochondral autograft transplantation None	–4.2 –9.0 –5.0 1.5
Synovitis	no yes	3.9 –5.4
Depth, mm	up to 7 more than 7	6.2 –2.8
Diameter, mm (ankle joint)	up to 10 10–15 more than 15	2.8 –1.9 –4.3
Diameter, mm (knee joint)	up to 10 10–20 mm more than 20	3.4 –2.1 –2.1
Area, cm^2 (ankle joint)	up to 1 1–2 more than 2	–0.1 –3.0 –4.3
Area, cm^2 (knee joint)	up to 1,5 1.5–3 more than 3	4.3 –3.1 –2.1
Volume, cm^3 (ankle joint)	up to 1,5 1.5–3 more than 3	–0.1 –3.0 –4.3

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Continuation of the table

1	2	3
Volume, cm³ (knee joint)	up to 2 2–4 more than 4	4.3 –3.1 –2.1
Kellgren & Lawrence	0 I II	4.8 5.6 –6.3

efficient (PC = +9.5), while those with excess weight show a significantly reduced likelihood of a positive outcome (PC = –9.0). Chronic bone-cartilage injuries have worse prognostic results (PC = –2.5) compared to injuries less than a year old (PC = +6.9), indicating the necessity for timely treatment of this type of injury. The size and depth of bone-cartilage injury directly correlate with treatment prognosis and have a high informational coefficient, which is an important factor in determining the further treatment strategy. The best prognosis is observed in stage 0–I osteoarthritis according to Kellgren & Lawrence (PC = +4.8; +5.6), while stage II already reduces effectiveness (PC = –6.3). The presence of deformity influences the choice of intervention strategy, as failing to restore the biomechanical axis of the limb makes it impractical to treat bone-cartilage injuries. Meanwhile, the absence of contracture (PC = +6.2) and axis deviation (PC = +3.2) are favorable signs. However, the localization of intra-articular bone-cartilage injuries only affects the technical aspects of the surgery and the need for arthroscopic or open access. Additional damage to the structures of the knee or ankle joint results in worse prognostic outcomes and requires additional surgeries to restore these structures.

Discussion

We have identified prognostic criteria in the treatment of patients with local intra-articular bone-cartilage injuries of the knee and ankle joints. The results obtained confirm the conclusions of other studies regarding the role of morphological and clinical factors in determining surgical intervention tactics [15–17].

The study by I. M. van Tuijn et al. [1] confirms that older patients and those with larger bone-cartilage injuries tend to have poorer outcomes after microfracturing. Additionally, patients with a BMI < 30 kg/m² experience better results from microfracturing compared to those with a BMI > 30 kg/m². A history of prior trauma or surgeries, such as partial meniscectomy or anterior cruciate ligament reconstruction, is also associated with worse long-term results in the surgical treatment of these injuries.

V. Gopinatth and colleagues [18] note that bone-cartilage injuries of 2–4 cm² in the knee joint, when treated with microfracturing, lead to further significant progression of osteoarthritis during long-term follow-up, with unsatisfactory subsequent physical activity levels and long-term clinical results after the intervention, although short-term results show positive dynamics in both the functional condition of the joint and return to physical activity. However, the quality of the regenerate obtained and the ability to withstand intense physical load decrease over time, which is especially important to consider in athletes or patients with high functional requirements [19].

Younger age and fresh bone-cartilage injuries are positive prognostic factors for the treatment of these injuries, which correlates with the conclusions of F. Migliorini et al. [20].

The need for total knee arthroplasty, according to the findings of J. S. Everhart et al. [21], increases when a patient has deep (full-thickness) bone-cartilage injuries with a diameter ≥ 2 cm, even at stage I–II osteoarthritis. The authors emphasize that regenerative and chondroplastic techniques are impractical for such significant injuries and suggest considering further stages of surgical treatment, especially in elderly patients.

In the study by J. S. Everhart et al. [22], it was observed that varus and valgus deformities, when combined with bone-cartilage injuries of the knee joint, result in poorer treatment outcomes, faster progression of degenerative-dystrophic changes, and unsuccessful surgical interventions. The authors also emphasize that excess body weight is a contributing factor, accelerating the progression of osteoarthritis and leading to less favorable treatment results.

In a prospective cohort study by P. H. Randsborg et al. [23], comparing microfracturing with arthroscopic debridement, better clinical results were achieved with microfracturing in cases of small injuries. However, the effectiveness of both techniques decreases as the size of the bone-cartilage injury increases.

Previous surgeries aimed at restoring articular cartilage, especially if their results were not sustained in the long term, are associated with a higher risk of unsatisfactory long-term outcomes after subsequent reconstructive procedures [24].

Most modern published studies for determining the size of bone-cartilage injuries rely only on the diameter or area, without considering depth or involvement of the subchondral bone. However, determining all parameters (depth, diameter, area, and volume) provides a more detailed picture, which, in

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turn, allows for more precise preoperative planning and the identification of the optimal surgical strategy and the overall appropriateness of chondroplastic surgeries.

Published studies evaluate BMI not just as something that adds to mechanical (axial) stress but also link it to metabolic changes. In our observation, we limited ourselves to bone-cartilage injuries in the knee and ankle joints, but for other joints, the coefficients of informativeness and prognostic criteria may change, especially for bone-cartilage injuries of the upper extremity joints. We relied on a standardized rehabilitation program, but individual factors of each patient, which may affect the final treatment outcome, were not considered. Also, according to the literature, patients undergoing restorative surgeries for bone-cartilage injuries are divided into groups before and after 40 years of age. However, in such cases, there is no individual assessment of the patient's desired future activity and functional requirements. A limitation of the observation is also the retrospective design, which is prone to systematic errors. Further prospective randomized studies are necessary to determine the effectiveness of treatment considering the prognostic coefficients and the prediction system for outcomes.

Conclusion

The study identified prognostic factors and informativeness coefficients that affect how effective treatment is for patients with local intra-articular bone and cartilage injuries in the knee and ankle joints. The success of treatment is determined by a combination of interrelated morphological, clinical, and history factors, with the most influential prognostic factors being: age, body mass index, size of the injury, osteoarthritis stage according to Kellgren & Lawrence, duration of the injury, limb axis deviation, and previous surgical treatment. The determination of prognostic and informativeness coefficients holds practical value for forming an individualized approach to selecting the optimal treatment strategy and improving long-term outcomes.

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

Prospects for Future Research. A limitation of this study is its retrospective design, which is prone to systematic errors. Further prospective randomized studies are needed to determine the treatment effectiveness, considering the prognostic coefficients and the prediction system for outcomes.

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Authors' Contributions. Omelchenko T. M. was responsible for gathering data and conducting a literary analysis; Levitsky E. A. wrote the article and performed statistical analysis.

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PROGNOSTIC FACTORS IN THE TREATMENT OF FOCAL OSTEOCHONDRAL LESIONS OF THE KNEE AND ANKLE

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