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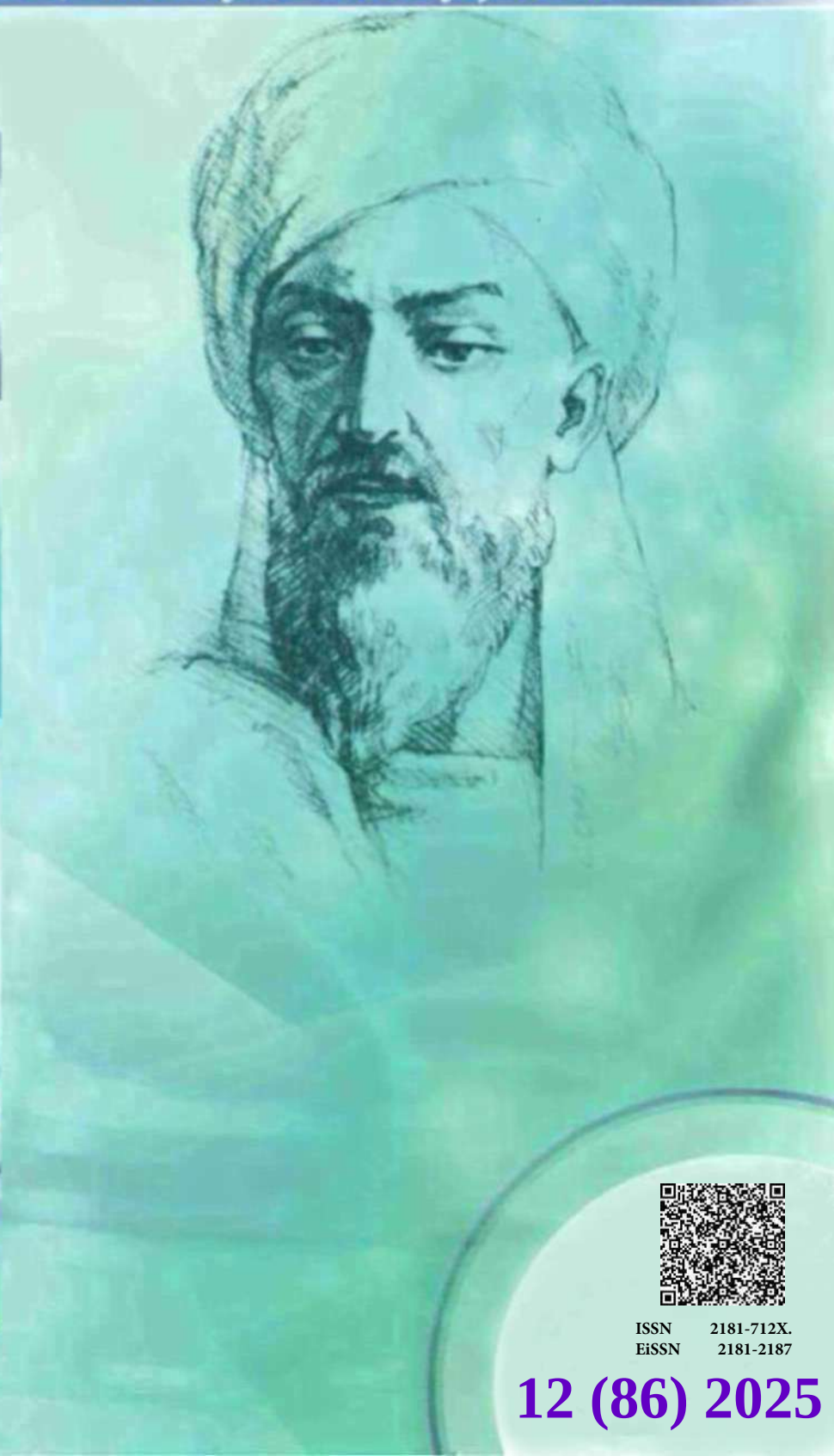


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## **ТИББИЁТДА ЯНГИ КУН НОВЫЙ ДЕНЬ В МЕДИЦИНЕ NEW DAY IN MEDICINE**

*Илмий-рефератив, маънавий-маърифий журнал  
Научно-реферативный,  
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## INTEGRATION OF PREDICTORS AND DIGITAL MODELS IN OPTIMIZING TOTAL HIP REPLACEMENT

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### ✓ Resume

*Degenerative and inflammatory diseases of the hip joint remain one of the leading causes of persistent disability and reduced quality of life in the elderly and working-age population. Total hip arthroplasty is an effective method of surgical restoration of joint function, but the frequency of early and late complications remains a significant clinical issue. The current paradigm of orthopedic surgery is shifting towards predictive and personalized medicine, which involves integrating clinical predictors, mathematical modeling, and digital technologies into the decision-making process.*

**Key words:** hip arthroplasty, mathematical modeling, predictors, personalized medicine, revision, complications, prognosis.

## ИНТЕГРАЦИЯ ПРЕДИКТОРОВ И ЦИФРОВЫХ МОДЕЛЕЙ ПРИ ОПТИМИЗАЦИИ ТОТАЛЬНОГО ЭНДОПРОТЕЗИРОВАНИЯ ТАЗОБЕДРЕННОГО СУСТАВА

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### ✓ Резюме

*Дегенеративные и воспалительные заболевания тазобедренного сустава остаются одной из ведущих причин стойкой инвалидизации и снижения качества жизни пожилых людей и лиц трудоспособного возраста. Тотальное эндопротезирование тазобедренного сустава является эффективным методом хирургического восстановления функции сустава, но частота ранних и поздних осложнений остается важной клинической проблемой. Современная парадигма ортопедической хирургии смещается в сторону прогностической и персонализированной медицины, которая предполагает интеграцию клинических предикторов, математического моделирования и цифровых технологий в процесс принятия решений.*

**Ключевые слова:** эндопротезирование тазобедренного сустава, математическое моделирование, предикторы, персонализированная медицина, ревизия, осложнения, прогноз.

## ЭНДОПРОТЕЗЛИ ЧАНОҚ – СОН БЎҒИМИ ТАРҚАЛГАН РАҚАМЛАШТИРИШ МОДЕЛИНИ ОПТИМАЛЛАШТИРИШ

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## ✓ Резюме

Эндопротезлаш чаноқ – сон бўғими дегенератив ва яллигланиш касалликлари доимий ногиронлик ва қариялар ва меҳнатга лаёқатли одамларнинг ҳаёт сифатининг пасайишининг асосий сабабларидан бири бўлиб қолмоқда. Умумий эндопротезлаш қўшма функцияни жарроҳлик йўли билан тиклашнинг самарали усули ҳисобланади, аммо эрта ва кеч асоратларнинг частотаси муҳим клиник муаммо бўлиб қолмоқда. Ортопедик жарроҳликнинг замонавий парадигмаси қарор қабул қилиш жараёнига клиник башоратчилар, математик моделиштириш ва рақамли технологияларни бирлаштиришни ўз ичига олган башоратли ва шахсийлаштирилган тиббиётга ўтмоқда.

**Калит сўзлар:** эндопротезлаш, математик моделиштириш, башоратчилар, шахсийлаштирилган тиббиёт, ревизия, асоратлар, прогноз.

## Relevance

Hundreds of thousands of such operations are performed annually in the world, and a significant increase in their number is predicted by 2030-2050. The high efficacy of total joint replacement is supported by registry data: the survival rate of modern implants exceeds 95% within 10 years after surgery. This means that the vast majority of patients experience long-term improvements in joint function and quality of life. However, an increase in the number of surgeries is also associated with an absolute increase in the number of complications, which, although relatively rare, can undermine the success of treatment. According to statistics, up to 3% of patients experience serious complications in the first 30 days after arthroplasty, requiring revision surgery. Among the early failures, infectious complications, such as periprosthetic infections, are the most challenging to treat. Other significant issues include endoprosthesis dislocations, perioperative thromboembolic events, and other risks. For example, without prophylaxis, deep vein thrombosis occurs in 45–57% of patients after total hip arthroplasty, and the incidence of pulmonary embolism reaches 0.3–6%, with up to a quarter of cases of pulmonary embolism being fatal. These data highlight the need to optimize approaches to perioperative management of patients.

This means taking into account individual predictors – risk factors and prognostic criteria that influence the outcome of surgery – using methods of mathematical prediction of outcomes. Identifying factors in a particular patient associated with an increased risk of complications or unsatisfactory outcome allows for pre-emptive correction of treatment and rehabilitation tactics. The use of predictive mathematical models and algorithms based on large clinical data sets opens up opportunities for an informed choice of the optimal prosthesis, fixation method, preventive measures, and other aspects of treatment. This review article presents the achievements of global science, the Commonwealth of Independent States (CIS) countries, and Uzbekistan in improving the effectiveness of hip arthroplasty using predictors and mathematical forecasting methods [1.3.5.7.9.11.13.15.17.19].

**The aim of the study:** The endoprotetic loop-number loop has been designed to improve optimization methods of the distributed digitization model.

## Results and analyses

The patient, the underlying disease, the type of surgery, and the postoperative care. Based on studies of large databases, a number of factors have been identified that significantly affect the risk of postoperative complications. These factors can be divided into modifiable (those that can be influenced before or during treatment) and non-modifiable factors. According to the consensus of international experts (2019), the following patient-related modifiable factors are included: overweight (high body mass index), smoking, alcohol and opioid abuse, and uncorrectable comorbidities. Knowledge of these predictors is of practical value – their identification allows for the stratification of patients by risk and the adoption of preventive measures (body weight correction, smoking cessation, compensation for concomitant diseases, etc.) before surgery, as well as the selection of the optimal intra- and postoperative management tactics. These tools summarize the impact of multiple co-occurring factors into a single numerical risk score. According to recent studies, one of the strongest predictors of poor outcomes (including the risk of re-operation) is a severe overall condition according to ASA and severe obesity (body mass index > 35). It has been found that patients with ASA III-IV and morbid obesity have a significantly higher chance of developing complications compared to relatively healthy individuals.

Another important factor is the underlying cause of the surgery: for example, in patients who undergo total hip arthroplasty for a femoral neck fracture (i.e., for urgent indications), outcomes are often worse than in patients undergoing elective arthroplasty for osteoarthritis, due to the age, emergency nature of the intervention, and prodromal complications of the injury.

As a result, we were able to achieve high prediction accuracy: four different models showed an area under the ROC curve (AUC) of over 0.80, which indicates excellent discrimination between patients with high and low risk of re-operation. Feature importance analysis revealed that the preoperative ASA status, obesity, and the reason for the first revision had the greatest impact on risk. Interestingly, the models demonstrated better benefits in terms of decision curve analysis compared to any simple strategies (operating or not operating on all patients). The authors note that such tools are suitable for optimizing patient management, for example, by allowing for the early identification of “at-risk” patients and the implementation of more aggressive preventive measures, or by choosing less invasive approaches for complex patients.

Mathematical models of joint biomechanics deserve special attention. Computer modeling using the finite element method and other engineering approaches is actively used to optimize the design and positioning of implants. An example is the research conducted by the Ilmok-BMCI group (Russian Federation): over the past decades, they have used computer modeling to develop designs for hip endoprostheses and predict their biomechanical behavior. These models have helped them select the optimal materials and shapes for the implant components to reduce stress on the bone and wear on the prosthesis. Domestic models of endoprostheses have been created and implemented, such as the cemented prosthesis "Sfen-C" and the cementless modular prosthesis "ILZA", which have shown good results in patients with osteoporosis. Mathematical modeling of the strength characteristics of the stem and acetabular component has also been used to justify their design. In general, engineering forecasting helps to predict the behavior of an implant under load at the design stage, including the distribution of pressure on the bone, the risk of micro-movements and loosening, the wear of friction pairs, and more. The data obtained in this way is used to improve the design of prostheses (for example, by adding a porous coating in areas of maximum stress, changing the angle of the endoprosthesis neck, and selecting alloys with the necessary elasticity and other properties) [2.4.6.8.10.12.14.16.18.20].

In addition, biomechanical models are used on an individual basis to plan surgery in complex cases. Computer simulations can be used to assess how a particular size and type of endoprosthesis will fit into a patient's anatomy and to predict the angle of installation of the components to ensure optimal range of motion without impingement. Precise preoperative planning, especially when combined with navigation and robotic installation technologies, significantly reduces the likelihood of complications such as component misalignment and endoprosthesis dislocation, which can directly impact the success of treatment.

As part of this work, a special information and analytical program was created, which automatically calculated the risk of developing hypercoagulation disorders in each patient based on objective clinical and laboratory criteria. The program took into account data on the state of the hemostasis system, medical history, the extent of the upcoming surgery, and other factors. As a result, it was possible to identify a group of patients at high risk of thromboembolic complications who required enhanced prevention measures. Moreover, based on the research, the author proposed an improved scheme for thrombosis prevention, which included prolonged pharmacotherapy for patients with signs of persistent thrombinemia. The implementation of this algorithm significantly reduced the incidence of venous thromboembolic complications after endoprosthetics.

In this area, work is also being carried out to create predictive models. For example, the journal "Genius of Orthopedics" published the results of the development of a method for predicting the likelihood of revision surgery on the hip joint with replacement of the acetabular component. The authors proposed an algorithm for assessing the condition of the peri-endoprosthetic bone and the fixation of the cup, which allows for predicting the risk of loosening and planning the revision procedure in a timely manner. Thus, the CIS has accumulated its own experience in predicting both general and specific complications of endoprosthetics.

The development of mathematical modeling in orthopedics in the CIS also deserves attention. Research on optimizing the design of endoprostheses using computational methods has already been mentioned.

The Republic of Uzbekistan, as part of the global and post-Soviet medical community, has also achieved significant success in the field of hip joint endoprosthetics in recent decades. With an increase in the number of surgeries performed (due to both the growing needs of the population and the improvement of the traumatological and orthopedic services), Uzbek specialists are actively implementing modern approaches to optimize results. Special emphasis is placed on studying the local characteristics of patients and adapting preventive strategies.

The sample included 227 patients aged 60–80, mostly women, who had suffered a femoral neck fracture. 110 of them formed the main group – they had total endoprosthetics performed initially, immediately after the injury, whereas 117 patients (control group) had prosthetics performed after a longer period after the injury. The results obtained convincingly demonstrated the benefits of early intervention. Immediately after surgery, 89.5% of all patients were noted favorable anatomic-functional outcomes.

However, in the main group, the proportion of positive outcomes was higher (93.2% versus 85% in the delayed prosthetics group), and unsatisfactory results were less common (6.8% versus 14.1%). In the long-term (long-term) period, there were no significant differences between the groups in terms of overall indicators (excellent results ~10%, good results ~32%, satisfactory results ~44% of patients), but the details showed interesting nuances. A direct relationship was found between the initial state of the bone tissue and the outcomes: patients without osteoporosis had significantly better and excellent outcomes (a total of ~40%) than those with osteopenia or osteoporosis. Moreover, an analysis of the effect of the endoprosthesis fixation method showed that the use of bone cement significantly improved the long-term outcomes in patients with osteoporosis.

Thus, among patients with cement fixation, ~60.9% of outcomes were considered good, while only ~39.1% of outcomes were considered good in patients with cementless fixation. This is an extremely important practical observation: it confirms that bone quality is a predictor of success, and suggests that in cases of poor bone conditions, it is preferable to use cement technology to enhance the stability of the prosthesis. This conclusion is already being implemented in the clinical practice of specialized centers in Uzbekistan. To objectively assess the severity of concomitant pathology, the authors used international comorbidity indices – the Charlson scale and the CIRS (Cumulative Illness Rating Scale). It was shown that with an increase in the comorbidity index, the prognosis of the results worsens: in patients with a high Charlson and CIRS score, unsatisfactory treatment outcomes were significantly more common (17.8% and 13.9%, respectively) than in patients with a low comorbid background. These data correspond to global observations and emphasize the need to optimize the overall condition of patients before surgery. Based on these findings, Uzbek specialists are increasingly involving related specialists (therapists, cardiologists, and endocrinologists) in the preoperative preparation of patients, as well as developing perioperative management protocols based on identified risk factors.

Hip joint endoprosthesis optimization in degenerative and inflammatory diseases is a multifaceted task that requires the integration of clinical experience, epidemiological data, and mathematical modeling. The review showed that a huge amount of information about predictors of arthroplasty outcomes has been accumulated on a global scale. Age, concomitant diseases, features of the main pathology, technical nuances of the operation – all this affects the final result. The key trend in recent years has been preventive personalization: identifying high-risk patients and applying targeted measures to them (preoperative optimization of their condition, selection of special implants or fixation methods, and enhanced postoperative monitoring). This approach has become possible thanks to the development of predictive models, from simple scoring systems to advanced artificial intelligence algorithms. These models allow us to predict the probabilities of certain events with high accuracy, thereby supporting clinical decisions with objective calculations. It is safe to say that further progress in endoprosthetics will be associated with an even deeper implementation of the principles of "evidence-based medicine" and mathematical modeling. The creation of multicenter registers and the integration of data using modern digital technologies will allow for the development of more advanced prediction models that are tailored to specific conditions. At the same time, the design of implants themselves will be improved, including the use of computer simulations, additive technologies (3D printing of individual prostheses), and new materials, which will expand the possibilities for customizing prostheses to meet the needs of each individual patient.

## Conclusion

This approach is already yielding tangible results in terms of reducing complications and improving functional outcomes. Continued research in this area, international collaboration, and the active implementation of scientific advancements in practice will further enhance the effectiveness and safety of endoprosthetics, ensuring patients have a long and active post-operative life.

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