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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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USE OF ARTIFICIAL INTELLIGENCE IN THE DIAGNOSIS AND TREATMENT OF ORTHOPEDIC DISEASES: LITERATURE REVIEW

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Abstract.

Introduction: Artificial intelligence techniques such as machine learning have made it possible to create neural networks for the recognition of MRI and X-ray images, which has improved the diagnosis and treatment of orthopedic diseases. **The purpose of** our review was to synthesize and analyze publications on the use of artificial intelligence in the diagnosis and treatment of diseases of the musculoskeletal system. **Materials and methods:** Utilizing a systematic narrative review method, we evaluated 348 publications from 2019 to 2024, with 201 of these being openly accessible. These publications were sourced from the Scopus and PubMed databases, focusing on key terms such as "Machine Learning", "Orthopedic Diagnostics", "Virtual Reality", and "Diseases of the Musculoskeletal System". We selected 89 publications for detailed analysis to identify the primary AI methods employed in orthopedics and to assess their diagnostic and therapeutic efficacy. During the literature analysis, the main areas were determined: the main methods of artificial intelligence used in orthopedics and the results of their application for diagnosis and treatment. **Results:** The analysis of publications showed the effectiveness of the use of AI in the analysis of MRI, CT and X-ray images. Techniques used by AI, such as machine learning, deep learning, virtual reality, and their effectiveness in performing diagnostic and treatment procedures were considered. **Conclusions:** The use of artificial intelligence in the diagnosis and treatment of orthopedic diseases demonstrated an increase in diagnostic accuracy, which contributed improvement of treatment results.

Key words. Surgery planning, orthopedic diagnostics, treatment protocols, machine learning, clinical effectiveness.

Introduction.

The development of technologies today allows us to consider the possibility of applying artificial intelligence (AI) in all areas of human life, and in the field of health care, AI has all the prospects for development. Today, the use of AI in hospital management, diagnosis and treatment is no longer surprising [1]. High efficiency has been demonstrated by the use of neural networks for diagnostics in the recognition of digitized X-ray and histological images, the implementation of personalized medicine and the development of modern medical areas such as genomics, genetic engineering, and nanotechnology. The use of AI during the diagnosis of patients and the analysis of biochemical results, data from ultrasound, X-ray or endoscopic examinations significantly shortens the time of making a diagnosis and reduces the percentage of errors, which allows doctors to start treatment faster and achieve the desired results. The use of AI helps in the early detection of the pathological process, for example, the analysis of MRI images allows establishing the early stages of rheumatoid arthritis and starting treatment before the appearance of irreversible changes in the joint [2].

The use of AI in the diagnosis and treatment of orthopedic diseases creates advantages, but at the same time there are problems that need to be solved. The diagnostic capabilities of AI depend on those data that have been uploaded to the databases, and therefore AI is not immune to false diagnoses, this creates a problem and the question arises: who is responsible. Usually, diagnosis and treatment, especially in complex clinical cases, are carried out through consultations with the participation of experienced specialists. The use of AI without taking into account the experience of experts can be wrong, especially in the treatment of rare diseases, about which information in databases is limited. AI models undergo machine learning, this process involves loading diagnostic or treatment algorithms, so incorrect training or loading incorrect information will cause incorrect diagnosis and treatment.

Young surgeons, traumatologists, resuscitators can learn the necessary skills in virtual conditions using the capabilities of AI. AI methods that allow you to immerse the future doctor in the environment of the operating room include augmented reality, virtual and mixed reality. Learning with the help of these technologies makes it possible to practice skills to the required level, and also not to worry about a negative result, which can cause the patient's condition to deteriorate, if we are talking about a real situation. The use of AI during the creation of a model of organs and systems of the human body allows the information obtained with the help of computer tomography (CT) to be recorded on the MIMICS intelligent server for storage. The obtained information can be used for 3D printing during injuries of internal organs and the musculoskeletal system. The use of 3D technology, which was first used in cardiac surgery and vascular surgery and has shown its effectiveness, allows you to approach the patient in a personalized way and consider the treatment of the patient taking into account individual characteristics. Today, 3D printing is used in surgical dentistry and orthopedics. With the help of AI and 3D model technology, in the future, it is possible to create personalized guides that can be used during surgical interventions. For example, the use of

such technology expands the possibilities of trauma surgeons during spinal operations for the correct placement of the screw insert, which determines the success of the surgical intervention. The use of AI in the treatment of spine diseases, namely during fixation of pedicle screws demonstrated that the use of robotic systems in spine surgery significantly improves the quality of patient care, as well as reduces the number of complications and shortens the length of stay of patients in the hospital [3]. Also, the use of AI reduced the radiation impact on the patient, as earlier the installation of th leg took place under radiological control, and the traumatization of the neurovascular elements also decreased [4]. Effectiveness was demonstrated by the use of the 3DP program during tibial osteotomy operations and during total knee arthroplasty. Diagnosis of fractures with the help of AI has significantly reduced the percentage of incorrect diagnoses during radiological examination, which determines the correct treatment tactics [5].

Today, one of the problems is the treatment of osteoporosis, which causes significant complications and is the cause of increased bone fragility and pain syndromes, especially in women during menopause [6]. In medicine, dual-energy X-ray absorptiometry is used to assess the risk of fractures in patients with osteoporosis. The use of AI makes it possible to more accurately determine risks, which can improve the quality of osteoporosis treatment and prevent fractures in elderly men and women [7].

The use of artificial intelligence in modern orthopedics is a promising direction for the diagnosis and treatment of diseases of the musculoskeletal system. The literature presents information on the effective use of AI capabilities in orthopedics for the analysis of MRI, CT, and X-ray images. Many publications consider the application of machine and deep learning methods that allow recognizing anomalies, classifying diseases, and obtaining automatically generated diagnoses. AI capabilities make it possible to treat a specific patient, which opens up the possibilities of personalized medicine. The ability of AI to analyze creates all the grounds for use in predicting the development of diseases and the occurrence of complications. AI can help in planning operational interventions and creating optimal algorithms. The use of AI makes it possible to implement robotic systems using 3D printing in personalized prosthetics and to create individual orthopedic solutions.

However, AI models can be inadequately trained if small or improperly selected data sets are used, which can lead to biased or incorrect diagnoses. AI algorithms can be sensitive to changing data collection conditions, which can affect the accuracy of diagnosis and prediction. The result that the doctor receives is not explained, which creates a “black box” problem. The integration of AI into clinical practice is not comprehensive, not all doctors trust AI and are skeptical. Also, not all hospitals have the opportunity to use AI in their professional activities. An equally important aspect is the issue of the loss of skills by doctors who rely only on AI. A feature of the use of AI in orthopedics is the need to take into account the biomechanical processes of the musculoskeletal system, which is quite difficult to model. Although the possibilities of AI and its ability to learn are really a breakthrough in medicine and significantly reduce the time for decision-making and are based on many years of experience, sometimes AI can give a false result.

The conducted studies are of a fragmentary nature and consider a separate issue regarding the use of AI in the diagnosis and treatment of orthopedic diseases, for example, in the diagnosis of diseases of the spine, knee or hip joint. To date, there are few publications that systematize information about the use of AI in the treatment and diagnosis of orthopedic diseases.

Research Problem.

The use of AI in the medical field is growing with the improvement of technical capabilities, so studying the features of the use of AI in the diagnosis and treatment of orthopedic diseases is important.

1. Our research will help systematize knowledge about the use of AI in the diagnosis and treatment of diseases of the spine, knee and hip joints (in the analysis of MRI, CT, X-ray images).
2. The research is aimed at getting acquainted with AI methods used in medical practice.
3. Carrying out a systematic review and studying the results of empirical research will acquaint the reader with the experience of scientists and doctors, which can be useful in work when using AI.

The data obtained from the literature indicate that research on the application of AI in the diagnosis and treatment of orthopedic diseases has been studied fragmentarily and there are few systematic reviews on this topic.

Research Focus.

The purpose of the conducted systematic review is to acquaint readers with AI methods used in medical practice, with the success of AI implementation in the diagnosis and treatment of diseases of the spine and joints, problems that may arise when using AI, as well as with the possibilities of modern AI achievements that effectively used in robotic systems for prosthetics. Also, the purpose of the study was to systematize the studied material and evaluate the current state of AI application in orthopedics.

Research purpose and research questions.

The purpose of our systematic review was to conduct a synthesis and analysis of research on AI methods used in medicine, the use of AI in the diagnosis and treatment of diseases of the spine and joint apparatus, and to familiarize with the current achievements of the capabilities of AI in the operation of robotic systems in prosthetics.

1. Conduct a review of the literature on the use of AI in the diagnosis and treatment of diseases of the spine and joint apparatus.
2. To evaluate modern achievements of AI in the work of robotic systems in prosthetics.
3. To analyze possible problematic issues that may arise on the way to the implementation of AI in clinical practice.
4. Outline the prospects for the use of AI in orthopedics.

Literature review.

AI tools used in medicine

AI has some tools that allow it to use the information provided and, more importantly, trust that information. With the help of machine learning (ML), it is possible to create whole networks with a certain set of data that can help in classification and recognition, for example, certain images: radiological,

histological. Machine learning has control elements: classification, regression and clustering. Machine learning requires prior training, which can be supervised, unsupervised, or supervised, which is most often used in the application of AI in medical diagnostics. The application of machine learning is designed to reproduce capabilities similar to neurons in the human brain. Certain points in the neural network correspond to biological neurons and a decision-making function is built into them, which can be a simple answer to the question "yes/no" or complex mathematical calculations [8]. A neural network can contain an unlimited number of artificial neurons, and they collectively make up a neural network. For MN, the following methods are used: linear regression, logistic regression, Bayes classifier, decision trees, neural networks [9]. A deep learning method can be achieved by connecting several neural networks. Neural network training is associated with constant comparison of the decision made, as well as making repeated decisions. During the training of the decision-making neural network, the results are evaluated, and incorrect results are corrected. Supervised training involves uploading information for the training set to the database. The lesson is that the result worked out by AI practically does not differ from the predicted one. The difference between the expected result and the obtained one is called “loss of function” and for a qualitative result of controlled learning, this difference should be minimal, which opens up opportunities for use in the future to compare unknown results with known ones contained in databases. The obtained results will depend on the quality of the data uploaded to the information systems, as well as on the complexity of the task. The peculiarity of learning with reinforcement is the absence of a known result in advance, and work is carried out under guidance and the result undergoes correction from the outside.

The unsupervised form of learning has no standard results for comparison. But the goal of this form of machine learning is to obtain certain regularities that form new scientific views.

There are certain elements of supervised and unsupervised learning such as regression, classification and clustering. Regression is a type of supervised learning. The application of this method is used in certain measurements, for example, measuring the location parameters of the central part of the intervertebral disc. Classification is a method used to establish certain criteria and is useful in making a diagnosis of the absence or presence of a disease, such as a broken bone. The clustering method allows you to group uncontrolled data, and then identify certain patterns [10].

AI uses natural language processing tools, applies algorithms to obtain semantic information. The method of linguistic programming was used as early as the 1950s to encode the necessary information used to improve the effectiveness of AI. Linguistic programming is used to process medical reports [11].

Convolutional neural networks (CNN) are used to analyze image data or video information. ANNs receive training during which the incoming information has a certain hierarchy and is passed with the help of convolutional layers through certain filters, which allows you to train the network to determine layer by layer in images: edges, textures and shapes, and then compare these parameters in unknown objects [12].

Application of AI capabilities in the diagnosis and treatment of diseases of the musculoskeletal system.

The possibilities of AI have found application in the diagnosis of diseases of the musculoskeletal system. Osteoarthritis, a fairly widespread disease today, which is associated with hypodynamia, an increase in body mass index, the aging of the population and the corresponding age-related changes, can significantly reduce the quality of life, be the cause of disability and cause the appearance of chronic pain syndrome and dysfunction of the musculoskeletal system.

The ability of AI to analyze images makes it possible to apply AI methods to detect diseases of the spine. AI allows analyzing the biomechanical features of patients, as well as predicting and calculating the impact of loads that can cause spinal deformities. It is the application of machine learning methods that opened up new possibilities for the use of AI in the therapy of spine pathology.

In the studies of Talaat W.M. the results of the use of AI in the diagnosis of TMJ osteoarthritis using cone beam computed tomography (CBT) were studied. Experienced specialists created a network of images that served as a reference for making a diagnosis. According to research results, AI achieved higher results in diagnosis than an expert radiologist [7]. For the application of AI in the recognition of orthopantomograms, the ResNet model of Karas was used, which sorted the images by categories: absent signs of OA, present signs of OA, orthopantomogram of a healthy person. According to the evaluation results of 1185 images, the AI showed high performance indicators. The assessment of the sensitivity of this model was identical to the sensitivity of the specialist, but the speed of diagnosis was significantly higher. AI can improve the possibility of diagnosis using the analysis of orthopantomograms, which is important given the availability of this method in most clinics [13].

In recent years, research has been conducted to find new diagnostic criteria for osteoarthritis, which can be asymptomatic for a long time with the sudden appearance of clinical signs and possibly irreversible changes in the musculoskeletal system. Liang Y conducted a search for critical genes that may be responsible for the development of osteoarthritis. Recent studies have provided data on specific genes that are the cause of osteoarthritis exacerbations, including receptor-interacting protein 3. AI machine learning techniques have helped identify the genes APOLD1 and EPYC, which are hallmarks of osteoarthritis. The role of these genes has been studied, and there is evidence in scientific publications that APOLD1 and EPYC cause the activation of mast cells, which are responsible for immune infiltration. Modern diagnostic methods allow the use of new markers for the diagnosis of OA, which reveals new pathogenetic mechanisms of OA development [14].

Pain syndrome is one of the key factors of maladaptation in knee joint damage. Acute or chronic pain in the knee can occur due to a number of orthopedic pathologies or vascular lesions. The causes of the development of many diseases of the musculoskeletal system can be infectious and inflammatory, autoimmune, trophic, tumor and dystrophic processes [15]. The most common knee pain patients present with are osteoarthritis, tendinitis, bursitis, patellar chondromalacia, gout, Baker's cyst,

rheumatoid arthritis, dislocation, meniscal tear, ligament tear, and bone tumor. The knee joint is subjected to the load of body weight every day, and during movements these loads increase significantly due to the increase in axial movements [16]. During diagnosis, most doctors use the results of MRI, which makes it possible to review the image of the problem area [17].

Pathological changes in the knee joint are associated with an increase in the SF marker and changes in the structure of the joint. With the help of AI methods, parameters of the knee joint are measured and the correlation between the marker of the degenerative process and quantitative changes is analyzed. X-ray images assessed the width of the joint space and determined the presence of osteophytes and sclerosis. The linear regression method was used to determine correlations between the signs of the pathological process on radiological images and the growth of the marker. As a result of the research, the correspondence between the obtained indicators was established [18]. Experts evaluated the AI method using neural networks VGG-16, ResNet-101 and Inception-v, which were used to study X-ray images of the sacroiliac bone in patients with sacroiliitis. First, training of neural networks was carried out, the results of which are evaluated by accuracy, sensitivity, specificity, precision and AUC (area under the ROC curve). The VGG-16 model, which underwent the process of machine learning during testing, demonstrated an increase in indicators: accuracy by 5.5%, sensitivity by 3.1%, specificity by 10.2%, precision by 9.8% and AUC by 0.04, compared from the ResNet-101 model, which was prepared. The application of trained AI machine networks: VGG-16, ResNet-101 and Inception-v3 showed high application efficiency, which can be useful in the diagnosis of sacroiliitis and reduce the need for MRI [19,20].

In the researches of Zhou S. et. al., they studied the issue of using AI to study the etiology, diagnosis, treatment and prognosis in the study of spine diseases. Similar research was conducted in 2020 by Shin et al. who used elements of deep learning to study the decrease in the cervical lordosis curve in men and women [21].

The technological capabilities of AI allow you to analyze images and make calculations, which reduces the time needed to make a diagnosis. In the studies of Belavy D.L. et. al. the application of AI is being studied on the created project “An intelligent low back pain classification tool guided by predictive evidence”. 300 women and men who had a history of non-specific manifestations of pain in the lower back took part in the study, the age of the patients was from 18 to 55 years. During the MRI examination, data were collected on the morphological features of the intervertebral discs and indicators of the condition of the spinal muscles. Pain thresholds were also assessed using special scales, anxiety and depression were determined. Based on patient indicators, subgroups were affected, and for machine learning, this information corresponded to clusters. Using a decision tree classifier allows you to obtain relevant indicators that characterize the cause of the appearance of non-specific pain in the lower back in contrast to control values. The goal of this project was to create protocols for the treatment of pain syndrome taking into account all classification features [22]. Glocker used machine learning to determine the location of the vertebral bodies. The use of this technique allows to establish the pathological location of the vertebral bodies on CT images in diseases of the spine: scoliosis, sagittal deformity. Huang studied the effectiveness of a deep learning-based program, Spine Explorer, that was used to automatically segment and count vertebrae and intervertebral discs during the analysis of MRI images of the lumbar spine. The use of the automated method has shown its effectiveness and accuracy during measurements [23]. The deep learning method covers the study of the segmentation of the lumbar spine and determines the quantitative parameters that create a complete picture of the condition of the vertebrae and intervertebral discs [24].

In the research conducted by Shen H., an automated program for measuring indicators of the lumbar spine is used in the analysis of axial lumbar MRI. The study states that studying pain sensations and determining the state of spinal muscles using the MRI method, as well as using the Spine Explorer deep learning program, allows you to accurately and qualitatively determine the parameters of spinal muscles, vertebral discs, and the spinal canal, which allows you to make predictions treatment, choose the most optimal tactics [25,26].

Xin B. reviews the use of a virtual reality simulator to teach trainee surgeons the technique of screw placement in the treatment of spinal injuries. The author came to the conclusion that the introduction of a virtual simulation model into the educational process improved the success rate of young surgeons to 82.9%, compared to the group where the technique of surgical intervention was studied from video material and was 74.2%. The quality of the procedure increased by 23.1%.

The study of the issue of treatment tactics for OA is presented in the studies of Jayakumar P. During the study, patients underwent three modules, which included: the first module familiarized patients with information about OA and assessed pain sensations using a special scale. In the second module, patients were familiarized with treatment tactics, with possible consequences, conducted a survey of the results they would like to achieve during treatment and the risks associated with joint replacement surgery. In the third module, patients report on the results achieved with the selected treatment tactics. The result of using AI and educating patients about certain risks of postoperative complications was an increase in the choice of conservative treatment [27].

Improvements in the technical capabilities of computer technologies and robotic systems allow the use of these technologies for the rehabilitation of patients after injuries. To date, pilot projects have proven themselves positively, such as: the use of exoskeletons to restore gait function, functional electrical stimulation, and others. In amputation of limbs today, the development of technology for the production of "smart" prostheses, which can be printed by 3D printing technology, is a promising direction [28].

Conclusions: The use of AI methods has demonstrated the high efficiency of using innovative methods in the diagnosis and treatment of orthopedic diseases, thanks to the use of machine and deep learning models, which allows you to quickly and accurately detect pathology and reduce the risk of errors, which improves treatment results. The use of AI makes it possible to

use the methods of virtual training of orthopedic surgeons and practice the prosthetics procedure to the required level, which improves the results of surgical treatment. AI is used today with robotic systems and can open new perspectives for improving prosthetics and developing exoskeletons. [29].

Materials and Methods.

The purpose of the literature review was to answer the following questions:

1. What artificial intelligence tools are used in orthopedics?
2. What are the results of using artificial intelligence to diagnose diseases of the musculoskeletal system?
3. What are the methods of artificial intelligence found use in the treatment of diseases of the musculoskeletal system?
4. We summarized the received information.

Sample and participants.

To systematize the studied literature, we used the PRISMA program (Liberati, Altman, Tetzlaff, Mulrow & Getzsche, 2009). The electronic literature was searched by keywords using the Scopus and PubMed search platforms. For further processing, we selected the articles that have the highest ranking in terms of h-index and h-median from 2019 to 2024.

Instruments and Procedures.

According to the systematic method, we conducted a narrative review of the literature on the topic of the use of AI in the diagnosis and treatment of orthopedic diseases. The search for sources for the review was carried out on the Scopus and Web of Science platforms, using specific keywords: “machine learning”, “orthopedic diagnostics”, “virtual reality”, “diseases of the musculoskeletal system”. These keywords were used because they are commonly associated with the topic of research on the application of AI in medical practice. The search terms “Machine learning”, “Orthopedic diagnostics”, “Virtual reality”, “Diseases of the musculoskeletal system” were introduced. To search for MeSH (Medical Subject Headings) keywords that correspond to the topic of AI for the diagnosis and treatment of orthopedic diseases, we selected the following keywords: Artificial Intelligence, Machine Learning, Pattern Recognition, Automated, Robotic Surgical Procedures, Orthopedics, Musculoskeletal Diseases. And also key combinations: Artificial Intelligence AND Orthopedic Diseases AND Diagnosis, Machine Learning AND Musculoskeletal Diseases AND Treatment.

• We selected for review only articles from 2019-2024.In this way, we got acquainted with the issues of AI methods used in medicine and the results of the implementation of AI in the diagnosis and treatment of orthopedic diseases. The justification for choosing the literature search period from 2019 to 2024 may depend on several key factors: carrying out a review of the literature in the period from 2019 to 2024 makes it possible to analyze the most current achievements in the treatment and diagnosis of orthopedic diseases, which allows reflecting the current state of knowledge, analysing new methods, tools and approaches. The choice of years is due to changes in clinical protocols, recommendations and standards, as well as the desire for relevance and coverage of modern events and scientific achievements.

• Inclusion and exclusion criteria were applied: Inclusion criteria: use of AI methods such as machine learning, deep learning, use of AI in the diagnosis and treatment of spinal and joint diseases, robotic systems in prosthetics, peer-reviewed articles were the results of original research.

• Articles that were available on the platform in full-text version were selected for further review.

For further analysis, we selected: review articles, meta-analyses, experimental studies, clinical cases

We applied language restrictions and analyzed articles written in English

The criteria for excluding publications for further analysis were the insufficient volume of the selection of publications, as well as the presence of adequate peer review.

• When working on the skin publication, we included only reliable and verified data in the status.

The articles reviewed by us provided information to countries in Europe: Germany, Great Britain, Asia: China, and North America: USA.

• We finally processed the selected articles and critically evaluated the received information, which highlighted problematic issues and determined the direction of further research (Figure 1).

During the review for further consideration, we did not include literature focusing on the application of AI in other fields of medicine: cardiology, neurology, oncology, even if it contained information related to orthopedics. Also, the exclusion criteria were articles on treatment and diagnostics in orthopedics without the use of AI, or with the use of technologies of semi-automated systems, without the use of AI algorithms. The research did not include articles without empirical data, case studies, or abstracts of conferences that did not undergo a thorough scientific review. Articles in which a randomized study was not conducted, there was no control group, as well as appropriate statistical data processing were not included in the analysis. Descriptions in articles of unvalidated AI algorithms were excluded due to unreliability of the results.

Data analysis.

We analyzed 348 publications from the period 2019-2024, of which 201 were freely accessible. The selection criteria for further analysis included the presence of specific keywords in the articles. The keywords we focused on were "Machine Learning," "Orthopedic Diagnostics," "Virtual Reality," and "Diseases of the Musculoskeletal System." A total of 89 publications met these criteria. After an extensive relevance and content review, we selected 45 sources that emphasized the role of AI tools in diagnosing and treating orthopedic diseases. This methodology allowed for a comprehensive and accessible review of the research topic using publications from Scopus and PubMed over the last five years (see Figure 2).

During the review of the articles, we critically approached the evaluation of each article, and the process took place in several steps: During the initial review, we analyzed the title of the article, abstract and keywords for compliance with the inclusion criteria. The next step was to evaluate the methodology, which looked at the research design, which helped to establish the reliability of the results obtained. For our study, a group

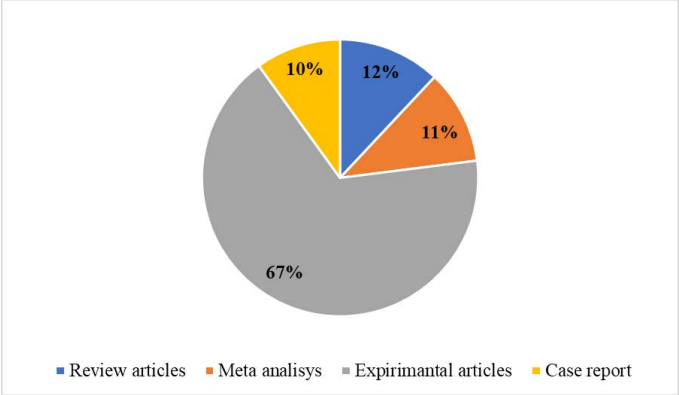

Figure 1. *Frequency distribution by types of studies.*

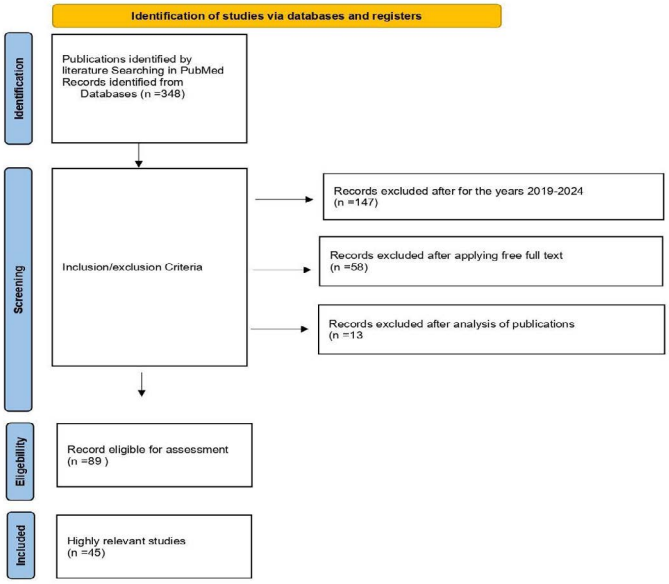

Figure 2. *PRISMA flow diagram.*

of adults was relevant to whom AI methods were used in the diagnosis and treatment of orthopedic diseases. We also paid attention to AI methods, which were studied in the article regarding their modernity and validity. During the literature review, we paid attention to the reliability of the results and conclusions given by the authors of the studies, as well as assessed the representativeness of the presented results. An important inclusion criterion was the assessment of the impact factor of the journal where the article was published, which testifies to the quality of resection. In this way, we determined the relevance of each article that met our research criteria.

The final step, which involved the selection of 45 articles out of 89 for the literature review, was based on several important considerations and methods to ensure high quality and relevance of the research. A double evaluation was carried out by two independent experts, which increased the objectivity of the selection process and ensured objective processing. If during the discussion the evaluators had disagreements in the selection of gender, another expert was involved. During the processing, the experts were guided by the criteria for inclusion and exclusion of relevant material, and also used a checklist to evaluate the indicators of each article. During the processing of articles, there were duplicates of the same scientists, who were removed from the further list by the evaluators.

As a result of individual processing and discussion of the articles that caused discussion among the evaluators, 45 articles were finally selected. The selected articles met the criteria of quality and relevance and fully disclosed the research topic.

Results.

Our systematic review highlighted the main directions of using AI in the diagnosis and treatment of diseases of the spine and joint apparatus and the use of robotic systems in prosthetics: the main goals of the original research, which were developed during the literature review: 1. Overview of AI technologies used in diagnosis and treatment orthopedic diseases, 2. The results of using AI in the recognition of MRI, X-ray, and CT images. 3. The results of the use of AI in the treatment of diseases of the spine and joint apparatus. 4. Problems that arise when using AI in the diagnosis and treatment of orthopedic diseases.

As the next direction of research, we determined which methodological approaches researchers used to find out the effectiveness of artificial intelligence in the treatment and diagnosis of orthopedic diseases (Table 1).

AI technologies used in diagnosis and treatment orthopedic diseases.

The use of AI technologies such as deep and machine learning contributes to the recognition of radiological images in osteoarthritis. AI is able to automatically recognize X-ray and MRI images and identify all structural elements of joints, which allows visualization of pathological signs of osteoarthritis [19]. The availability of thousands of examples of images with a known diagnosis in the digital databases allows classifying the stage of osteoarthritis, for example, according to the Kellgren-Lawrence scale, which allows prescribing adequate treatment [24].

Artificial intelligence (AI) significantly improves screw placement in spine surgery. AI, based on the analysis of MRI and X-ray images, creates a real three-dimensional model, which makes it possible to plan the optimal location of the screws, taking into account the individual anatomical features of patients [10]. The use of robotic systems makes it possible to install screws with minimal deviation and avoid damage to blood vessels and nerves. AI, during the procedure, corrects errors in the real-time system, which reduces the time taken for the operation and contributes to faster recovery [24]. Thanks to the accuracy and speed of data processing provided by AI, the time required to install screws is significantly reduced. This reduces the duration of the operation, which reduces the risk of infections and other postoperative complications.[9] AI is used to train surgeons who practice the complex screw placement procedure virtually in a virtual operating room using virtual reality technology. This helps young or less experienced surgeons perform complex operations at a high level [7].

The issue of which AI methods are used for the analysis of orthopedic images in the diagnosis of diseases of the musculoskeletal system was also worked out. According to the literature, specific methods such as machine learning, deep learning, and various computer vision algorithms are used for

Table 1. *Results of a literature review on the use of artificial intelligence in the diagnosis and treatment of orthopedic diseases.*

Author name/ Year of publication	AI technologies used in diagnosis and treatment orthopedic diseases	Using AI in the recognition of MRI, X-ray, and CT images.	Using AI in the treatment of diseases of the spine and joint apparatus.	Problems when using AI in the diagnosis and treatment of orthopedic diseases.
Li J. 2020 [3]	+			
Liu P.R. 2021 [2]	+	+	+	
Bangeas P. 2019 [4]	+	+	+	
Kuo R.Y. 2022 [5]	+			+
Carey J.J. 2022 [6]	+	+	+	
Talaat W.M. 2023 [24]	+	+		+
Greene C.S. 2020 [52]			+	+
Tsai C.M. 2020 [25]	+	+	+	
Diwan T. 2023 [12]		+	+	+
Hiraiwa T. 2019 [18]	+	+		
Garwood E.R. 2020 [39]		+	+	
Kumar J. 2020 [53]	+			+
Choi E. 2021 [41]	+		+	+
Üreten K. 2023 [46]		+		+
Shin Y. et al. 2020 [21]	+	+	+	
Wirries A. 2022 [43]	+			
Jansen M.P. 2023 [17]			+	
Myers T.G. 2020 [13]		+	+	
Schmidt J.K. 2021 [50]	+	+		
Niemeyer F. 2021 [11]	+	+	+	
Huang J. 2020 [10]		+	+	
Shen H. 2021 [26]	+	+		
Cina A. 2024 [16]	+			+
Xin B. 2020 [48]		+	+	+

such methods. These methods include image classification, image segmentation, anomaly detection, texture analysis, biomechanics and movement analysis, treatment outcomes and predictions (Figure 3).

Use of AI in the recognition of MRI, X-ray, and CT images.

The application of the image classification method using CNN networks allows classification of MRI, CT and X-ray images. Neural networks contain data of key signs of certain pathologies, such as osteoarthritis, fractures, tumor processes, which can be detected during the analysis of images that are sent to diagnosis using AI [30] (Figure 4).

The image segmentation method uses U-Net networks. Using this method, according to the literature, the image can be divided into certain areas, which is very convenient during the diagnosis of spine diseases [31]. And segmentation reveals the pathological process depending on the structure of the tissue: bone, muscle, joint. Another Fully Convolutional Networks (FCN): used for bone and cartilage segmentation [32].

The method of deep learning and convolutional neural networks allow to automatically detect pathological processes in fractures, osteoporosis, and these methods are also useful from the point of view of sorting images according to the pathological process. Anomaly Detection Networks uses search tools that allow you to distinguish a reference image of a healthy structure from a pathological one [33].

Today, the methods of using 3D-CNN 4 are described, which allow you to create ZD images and recognize them. This technique allows viewing images of bones and joints in a three-dimensional format, which is important when planning surgical interventions [34].

Generative Adversarial Networks has prospects for use in prosthetics, as it can be used to restore damaged areas of bones or joints [35]. With the help of the Radiomics program, it is possible to determine structural changes in the bone tissue, which the doctor cannot visually determine. Such a program provides information about changes in bone mineralization [34].

Analysis of movements and biomechanics can be carried out using the program Recurrent Neural Networks. This program evaluates changes that can be seen on video MRI, CT, ultrasound. In this way, it is possible to determine the presence of functional changes [36].

The Motion Analysis Algorithms program helps visualize joint movements and detects pathological joint conditions, such as dysplasia, or ligament tears, or meniscal damage [37].

Predictive Modelling evaluates the results of treatment and creates a prognosis of the disease and can also predict the results of surgical interventions or conservative treatment [35]. The results of the use of AI in the treatment of diseases of the spine and joint apparatus. Next, we considered the question of what types of orthopedic diseases are diagnosed by AI and presented in the literature we analyzed (Figure 5).

The literature reviewed shows that AI can analyze X-rays or MRIs to detect signs of osteoarthritis, rheumatoid arthritis, and other forms of arthritis. AI can detect signs of pathological diseases, such as changes in the joints, changes in the size of the joint space, or the presence of osteophytes [30]. Using

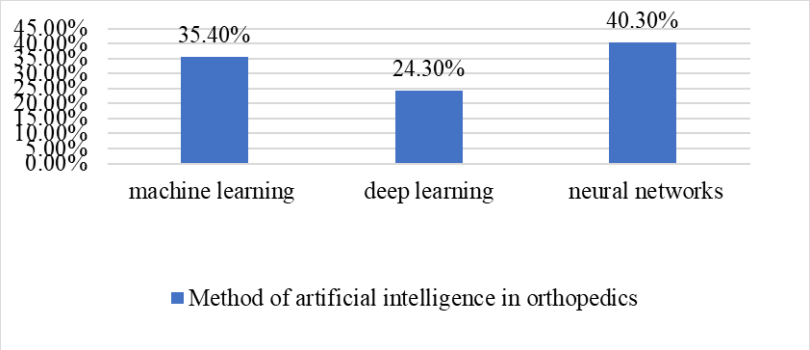

Figure 3. *Methods of artificial intelligence in orthopedics.*

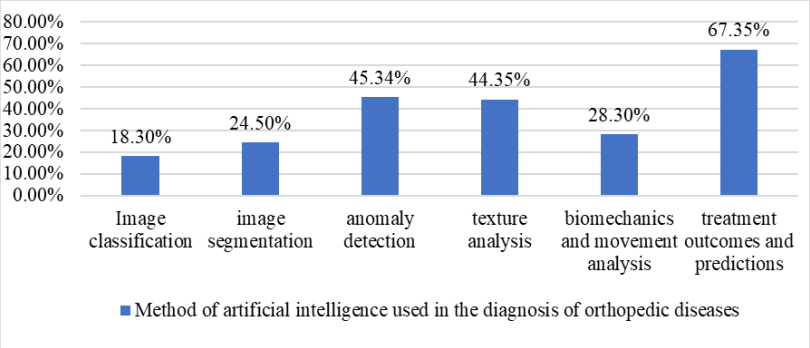

Figure 4. *Methods of artificial intelligence used in the diagnosis of orthopedic diseases.*

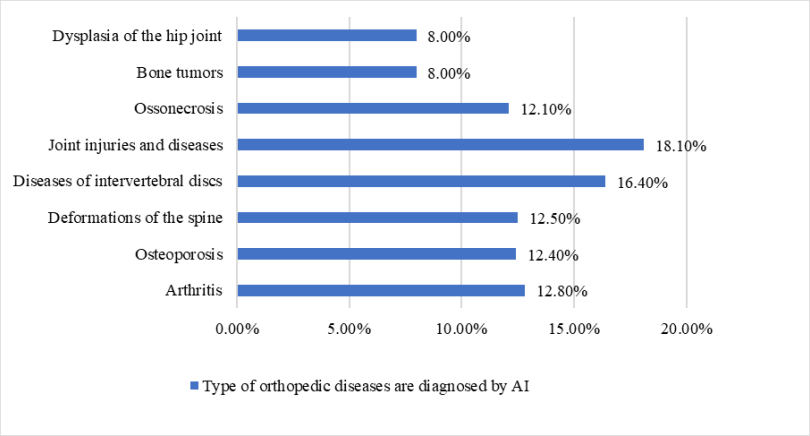

Figure 5. *Types of orthopedic diseases are diagnosed by AI.*

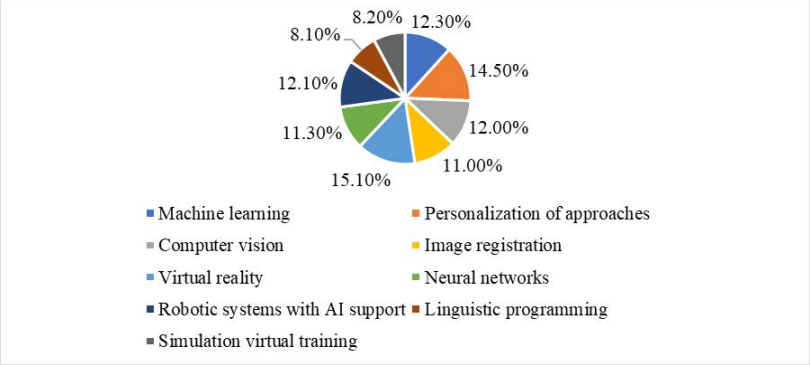

Figure 6. *AI technologies used in orthopedics reveals.*

bone densitometry, AI can predict susceptibility to fractures by assessing bone mineralization, and also helps determine the degree of osteoporosis [38]. The ability of AI to analyze MRI images and X-rays allows to diagnose scoliosis, kyphosis and lordosis and other curvatures of the spine. Ligament tears, meniscal and joint injuries are often analyzed using AI, which detects pathological changes in MRI, CT or X-ray images [39]. Today, AI helps in the diagnosis of pathological changes in the intervertebral discs. Analysis of MRI or CT with the help of AI allows to detect protrusions, changes in the location of the central disk, which can be combined with chronic pain or neurological symptoms. AI and the method of deep and machine learning allow effective diagnosis and planning of operative treatment and prognoses [35]. Examining tissue texture and changes can help in early detection of bone tumors. AI can help differentiate between benign and malignant bone tumors by analysing characteristic features on medical images. AI can detect signs of osteonecrosis by analysing MRI images, as well as signs of bone tissue death due to impaired blood supply, which is characteristic of osteonecrosis [34]. By analysing ultrasound or X-ray images, AI can diagnose dysplasias that can lead to dislocation or other hip problems in children and adults [40].

The study of AI technologies used in orthopedics reveals the following directions in the literature: machine learning, personalization of approaches, computer vision, image registration, virtual reality, neural networks, robotic systems with AI support, linguistic programming, simulated virtual learning (Figure 6).

AI capabilities today help in the development and improvement of exoskeletons and smart prostheses. AI helps to analyze signals from muscles or from motoneurons of the cerebral cortex about the intention to carry out a movement. Exoskeletons equipped with AI capabilities have the ability to process received signals and react almost instantly, ensuring smoothness and naturalness of movements.

Problems that arise when using AI in the diagnosis and treatment of orthopedic diseases.

The use of AI has significant prospects in the diagnosis and treatment of orthopedic diseases, but there are also some problems that need to be considered and solved. AI algorithms that are used to diagnose complex orthopedic diseases must be sufficiently reliable, as inaccuracy can lead to incorrect diagnosis and inappropriate treatment. Algorithms for the use of AI are based on known data, therefore, the treatment of rare diseases, about which there is limited information, may not be sufficiently justified due to an insufficient amount of clinical data, which reduces the accuracy of diagnosis with the use of AI algorithms. An important issue in this aspect remains the issue of responsibility for the error made by AI algorithms. The result provided by AI is usually not supported or explained by anything, especially when it comes to the work of deep neural networks that function as "black boxes". The widespread use of AI in medical practice requires the integration of AI algorithms into electronic medical records, which is currently problematic from a technical point of view. Researchers note that the use of AI contributes to the development of personalized medicine and can take into account the individual characteristics of patients, but creating algorithms for each patient is quite problematic, and the presence of concomitant diseases can change the effectiveness of standard solutions of AI algorithms. Perception of AI capabilities may not always be accepted by medical professionals, as medical staff must be trained to use AI algorithms, and AI may be seen as a threat to medical competence.

A possible leak of information about personal data of patients creates a threat of mistrust of the medical institution, or even legal problems. Treatment of orthopedic diseases is often surgical intervention, and in this aspect the question arises whether it is possible to automate the treatment process using robot surgeons, whether there is trust in the decisions made by AI algorithms, especially when it comes to surgical treatment.

The development of technologies also improves the capabilities of AI, which contributes to the growth of the role of AI in the diagnosis and treatment of orthopedic diseases.

Discussion.

The conducted systematic review reveals the application of AI, which is used in medical practice today. It also introduces the methods of AI used in modern orthopedics in the diagnosis and treatment of diseases of the spine and joint apparatus and the achievements of AI in robotic systems and prosthetics.

The purpose of using AI is not to replace a doctor, but to help in making a decision when making a diagnosis and deciding on treatment tactics. The possibility of using AI in this direction is related to the possibility of AI to reproduce cognitive functions, such as learning and decision-making. For the application of AI in medicine, it is necessary to create high-quality databases, powerful computers, reliable servers, as well as open source algorithms [41].

The analysis of publications demonstrated the high efficiency of machine learning methods, which is confirmed in the works of other researchers. The improvement of machine learning methods allows to combine clinical examination data, patient complaints with the results of MRI, X-ray or histological images, which will provide a comprehensive picture of the disease and facilitate decision-making about treatment and the need for surgery. Therefore, in recent years, there has been an increase in studies that help to visualize pathological changes in the musculoskeletal system, especially the spine [42].

The capabilities of AI make it possible to predict its application in image interpretation, which is demonstrated by the results of the analysis of publications. Recognition of images with the help of AI, obtained on X-ray machines, MRI, CT, is currently considered the full cycle of processing from the request to obtaining a complete result with a description. Solving non-iterative tasks with the help of AI allows you to create patient examination protocols, systematize test data of clinical examinations, and conduct planning. When interpreting AI images, it is possible to determine bone age, conduct an examination for signs of osteoporosis by bone composition, determine the presence of cracks and bone fractures, and determine spine pathologies [25].

The loading of medical information regarding etiological factors, diagnosis, clinical manifestations and treatment is the source for the work of AI tools. Improving the technological

capabilities of artificial intelligence and its training will only increase the accuracy and sensitivity of the use of AI methods for diagnosis and treatment in the future. The capabilities of AI to process large volumes of information make it possible to establish the etiological factors of diseases of the musculoskeletal system, which will allow early intervention and treatment [26]. In surgical orthopedics, the use of AI has found application for processing images, predicting risks and possible complications, as well as adopting optimal treatment tactics [28].

AI has shown effectiveness in the diagnosis of diseases of the joint apparatus. Early manifestations of temporomandibular joint osteoarthritis (TMJ) are quite difficult to visualize and the analysis of the results of cone beam computed tomography (CPCT) is not always correctly interpreted. Mistakes in diagnosis can be the cause of imperfect treatment protocols, which can contribute to the progression of the pathological process and detect it in the later stages, when the changes will be irreversible. The pain syndrome that often accompanies osteoarthritis and the nature of this pain may have a neuropathic nature and may not correspond to the severity of the disease, which may create additional difficulties in diagnosis. Early diagnosis is the key to successful treatment, while imperfect diagnosis hinders this process [43,44].

Appropriate diagnostic criteria were developed for the diagnosis of TMJ disorders, which were updated in 2014. According to clinical observations and radiographic studies, which make it possible to detect the destruction of the articular surface and bone changes, in the form of erosions, osteophytes, cysts. But the interpretation of X-ray signs of osteoarthritis is subjective and needs improvement [45]. For the successful use of AI, a deep learning technique is applied, which makes it possible to improve diagnostic results and speed up diagnosis, as well as improves the ability to make the right decisions when prescribing treatment, taking into account the individual characteristics of the patient. As an auxiliary element in medical visualization, a neural network is used, which contains a loaded database of images with a known diagnosis [46]. Experts note that such results reduce subjectivity in making a diagnosis, but at the same time, there is a need to expand the capabilities of the neural network by downloading data from patients' medical histories, as well as the results of other examinations, which will create a more objective picture of the disease [47]. Orthopantomography is often used to diagnose pathological changes in the TMJ, which gives a lower radiation dose than CT.

Today, technological capabilities allow combining AI methods with innovative medical areas, such as nanotechnology, bioinformatics, genomics, and others. The use of AI methods in combination with bioinformatics methods, which make it possible to establish the structure of genes, demonstrated that APOLD1 and EPYC are present in patients with signs of osteoarthritis, which determined new directions in the immunotherapy of such patients [12].

Other studies report a possible combination of OA and metabolic syndrome (MS). As noted, metabolic syndrome and OA may be immune in nature and associated with the expression of genes that contribute to the development of both MS and OA. To identify critical genes, AI methods were used, namely machine learning, which searched the gene coexpression network with subsequent application of nomograms. Immune cells, which are inherent in OA, were found by the method of immune infiltration. Patients with OA and MS showed signs of immune cell dysregulation, and gene analysis revealed eight critical genes (FZD7, IRAK3, KDELR3, PHC2, RHOB, RNF170, SOX13, and ZKSCAN4) that may have diagnostic value in the combination of OA and MS [17].

Machine learning allows you to assess pathological changes in knee joints and interpret the diagnosis based on images from the neural network (ligament rupture, meniscus, cartilage damage). More information can be obtained using deep learning. The use of convolutional neural networks, which perform multi-stage operations on the type of brain neurons and can evaluate pathology from different positions. Such a neural network can be used to classify and determine the degree of the pathological process. According to experts, AI methods: machine and deep learning have high capabilities for recognizing pathological processes, and further monitoring changes that occur during treatment or during the progression of the pathological process [19].

Thanks to the ability of artificial intelligence to process huge data, it is possible to better analyze the etiology to achieve early intervention and provide assistance for further treatment.

The analyzed literature presents publications that reveal the issue of using AI in the diagnosis of diseases of the spine and joint apparatus. Today, the percentage of patients with spine disease is increasing, which is associated with the aging of the population, excess body weight, hypodynamia, and the use of gadgets that disrupt posture. Imaging techniques that can produce images such as MRI, CT have recently become available to more patients and the number of images that can be uploaded to a neural network for machine learning is increasing.

In Schmidt's research, the classification tree method is used to create maps of the probable location of the central part of the intervertebral disc on MRI images, which is important when comparing control images with unknown ones that come for diagnosis. Machine measurement achieves better accuracy compared to manual measurement and the error is reduced to 6.2 mm. Niemeyer F. Creates a reliable classification model of degeneration of intervertebral discs with the help of artificial intelligence [33].

The implementation of AI for the recognition of MRI images can significantly increase the accuracy and speed of diagnosis. Today, the capabilities of AI make it possible to recognize pathological changes in the cartilage tissue of a joint, which is associated with the prevalence of this pathology and the presence of a large number of available images in repositories [19].

The review of publications highlighted the issue of using AI in mastering surgical skills during surgical interventions in orthopedics. The use of virtual reality technology in Logishetty K's research allows the surgeon to be placed in a virtual operating room for hip replacement surgery. To evaluate the effectiveness of using virtual reality in mastering the necessary skills, efficiency criteria were used that determined

the quality of surgical intervention, cognitive and motor skills during positioning of acetabulum components and femoral neck osteotomy. According to the results of the study, the author notes the progress demonstrated by trainee surgeons in acquiring surgical skills, which was demonstrated during the procedure and was determined by the correct sequence of actions, movements and spatial accuracy. Young specialists can transfer these skills to a real physical environment [48].

In other studies, the author provides data on the use of virtual reality, which helps track and control the surgeon's movements in the operating room and allows the trainee doctor to immerse himself in the environment during hip arthroplasty. Evaluation of the implementation of virtual reality was determined using technical surgical efficiency. The number of errors in the orientation of the acetabular component and the time of the procedure were also evaluated. The effectiveness of the use of virtual reality was shown by Hooper J.'s research, which described simulated virtual improvement of hip joint replacement skills [49]. The application of AI capabilities for the treatment of diseases of the musculoskeletal system at the molecular level considers the delivery of nucleic acids to cells that are involved in the pathological process. Namely, the possibility of miRNA-140 delivery to chondrocytes is being considered by the method of bioinformatics and nanotechnology [50].

Treatment tactics for osteoarthritis of the knee joints that require surgery and joint replacement are combined today with patient-reported outcomes, which helps to make the right choice of treatment tactics [51]. The application of AI creates personalized treatment approaches. And machine learning uses a set of data to make connections and choose tactics. During the assessment of treatment tactics and possible consequences, the ability of AI for analytical learning is used. If you use the capabilities of machine learning, clinical data and data reported by the patient, you can get the most optimal approach to treatment [52]. The randomized trial evaluated treatment strategies using Joint Insights, an artificial intelligence program that provides patient education, interactive preference assessment, and personalized outcome reports generated by a machine learning algorithm using a large national data set [53].

The application of AI methods has demonstrated the high efficiency of using innovative methods in the diagnosis and treatment of orthopedic diseases, thanks to the use of machine models and deep learning models, which allows for quick and accurate detection of pathology and reduces the risk of errors, which improves treatment results [54]. However, there are certain risks that limit the use of AI. The accuracy and reliability of AI algorithms used in diagnostics depend on the data that was loaded and how the neural networks were trained [55]. Errors in algorithms will lead to diagnostic errors, treatment tactics and prognosis. Deep learning, as a method used by AI, can provide unsupported information that can be wrong. There is a legal aspect of who is responsible for AI errors, which can also limit the application of this technique. If AI is trained on data based on age, gender, and ethnicity, data analysis and interpretation may be biased and therefore incorrect. To date, AI does not have a sufficient base of clinical trials, which limits the large-scale application of AI in diagnosis and treatment.

The use of AI in the diagnosis and treatment of orthopedic diseases opens up new perspectives in increasing efficiency. The use of computer vision technologies will increase the accuracy of analysis of X-ray images, MRI and CT, and in the future, the smallest signs that remain unnoticed by traditional approaches may contribute to the detection of pathologies in the early stages. Osteoporosis today is the cause of disability of a large part of the population, the use of automatic screening can be a preventive measure to detect early signs of the disease and successful treatment. The increase in the amount of data in AI networks will strengthen the position of personalized medicine in the future, as more and more individual characteristics will be taken into account, which will allow creating individual prostheses taking into account the biomechanics of a specific patient.

Improving the capabilities of AI, the ability to constantly learn and analyze data, in the future will be able to perform automated surgical interventions with minimal human intervention, which can increase the accuracy of surgical intervention and reduce the risks of human errors. Today, the direction of applying AI in rehabilitation technologies, which allows monitoring and managing the rehabilitation process, as well as creating rehabilitation programs, looks promising. The use of virtual and augmented reality opens up new opportunities for individual rehabilitation by creating a virtual interactive environment that allows you to perform training exercises and adapt to progress.

Today, work is being done on the development of miniature biosensors that will be able to provide long-term monitoring of the condition of bones and joints.

The application of AI in combination with biomechanical modelling can be used to study the impact of orthopedic diseases on the motor activity of patients, which will allow predicting the progression of diseases such as osteoarthritis or scoliosis, as well as predicting treatment outcomes. The use of AI provides a multidisciplinary approach and will contribute to the integration of AI with medical fields that can provide comprehensive treatment and associated pathologies. Implementation of the digital twin’s method can provide an individual approach to patients regarding surgical interventions and rehabilitation methods. In order to expand the use of AI capabilities in the future, ethical and legal issues must be resolved, which will contribute to the development of standards for the implementation of AI in medical practice.

Conclusion.

After reviewing the literature, we can conclude that the use of AI in the diagnosis and treatment of orthopedic diseases has increased in recent years. AI technologies such as machine learning, deep learning, and virtual reality have proven highly effective in the analysis of MRI, CT, and X-ray images, which helps to increase the accuracy of diagnosis and improves the results of treatment based on individual characteristics. Also, the obtained data indicate that the use of neural networks for image recognition more accurately identifies pathologies, including fractures, degenerative changes in joints, intervertebral hernias, which reduces the time required for diagnosis and improves accuracy, reducing the risk of human errors. The analysis of publications showed that the application of AI is quite effective when planning operations on the spine and joints. Carrying out

surgical interventions using robotic systems controlled by AI ensures the accuracy of the manipulations, which helps to avoid errors and promotes rapid recovery in the postoperative period. At the same time, the use of AI can create certain challenges and problems. The question of ethics and the preservation of personal data arises. The use of AI can lead to dependence on the capabilities of AI, which will reduce the qualifications of doctors. There is the issue of integrating AI into medical systems, which is associated with technical limitations and the lack of standards regarding the use of AI in medical practice.

The use of AI is undoubtedly a significant step in the treatment and diagnosis of orthopedic diseases.However, for the comprehensive application of AI, it is necessary to solve the problems associated with the use of AI in medicine.

Improving the capabilities of AI is a promising direction for planning operational interventions. The use of 3D modeling and the possibility of 3D printing will allow surgeons to carefully plan operations taking into account the anatomical features of the patient, which is promising in individual prosthetics. The use of AI is undoubtedly a significant step in the treatment and diagnosis of orthopedic diseases. However, for the comprehensive application of AI, it is necessary to solve the problems associated with the use of AI in medicine.

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