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Artificial intelligence in endodontics: current achievements and future prospects. A literature review

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Abstract

INTRODUCTION. The article explores the current achievements and future prospects of artificial intelligence (AI) in endodontics, emphasizing its applications in diagnostics, treatment planning, quality control, outcome prediction, telemedicine, and educational processes. AI is highlighted as a transformative tool that enhances precision, standardization, and personalization in endodontic practice.

AIM. To systematically analyze the current state of AI application in endodontics and outline directions for further research and implementation.

MATERIALS AND METHODS. The study involved a thorough review of scientific literature obtained from major databases such as PubMed, Scopus, and Web of Science over the past five years. A critical evaluation of these publications assessed the effectiveness of AI in clinical practice and educational programs.

CONCLUSIONS. AI significantly enhances diagnostic accuracy, optimizes treatment planning, improves quality control, and expands opportunities in telemedicine and dental education. However, challenges such as high implementation costs, data security concerns, the absence of standardization, and the need for regulatory frameworks persist, necessitating further research and development of universal solutions.

Keywords: artificial intelligence, endodontics, diagnostics, treatment planning, quality control, telemedicine

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Искусственный интеллект в эндодонтии: текущие достижения и перспективы будущего. Обзор литературы

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Резюме

ВВЕДЕНИЕ. В статье рассматриваются современные достижения и перспективы использования искусственного интеллекта (ИИ) в эндодонтии, с акцентом на его влияние на диагностику, планирование лечения, контроль качества, прогнозирование исходов, телемедицину и образовательные процессы. Введение посвящено роли ИИ в изменении подходов к эндодонтической практике, где точность, стандартизация и персонализированный подход становятся ключевыми аспектами.

ЦЕЛЬ ИССЛЕДОВАНИЯ: систематизация и анализ текущего состояния применения ИИ в эндодонтии, а также в определении направлений для дальнейших исследований и практического внедрения технологий.

МАТЕРИАЛЫ И МЕТОДЫ включают комплексный обзор литературы на основе ведущих баз данных, таких как PubMed, Scopus и Web of Science, охватывающий последние пять лет. Проведен критический анализ публикаций, оценивающих эффективность ИИ в клинической практике и образовательных программах.

ВЫВОДЫ подчеркивают значимость ИИ как мощного инструмента, способного улучшить диагностику, планирование лечения и контроль качества, а также расширить возможности телемедицины и обучения стоматологов. Несмотря на его преимущества, остаются вызовы, такие как высокая стоимость внедрения, защита данных, недостаток стандартизации и необходимости нормативного регулирования, что требует дальнейших исследований и разработки универсальных решений.

Ключевые слова: искусственный интеллект, эндодонтия, диагностика, планирование лечения, контроль качества, телемедицина

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INTRODUCTION

Artificial intelligence represents one of the most promising technological advances of the Artificial intelligence (AI) is one of the most significant and promising technologies of the modern era, revolutionizing traditional approaches across various domains, including medicine and dentistry. In recent years, AI has firmly established itself in medical practice, offering novel opportunities to enhance the efficiency of diagnostics, treatment planning, and clinical outcomes. In the context of endodontics – a specialized field of dentistry focused on the treatment of pulp and periapical tissue diseases – AI demonstrates transformative potential, fundamentally altering approaches to diagnostics and comprehensive therapy.

Endodontics, as a discipline requiring high levels of precision and accuracy, has particularly benefited from the integration of AI. The processing and analysis of medical images, such as radiographs and cone-beam computed tomography (CBCT) data, have become significantly more accurate and efficient due to AI implementation. This advancement has substantially improved diagnostic quality, minimized human error, and elevated the standards of dental care delivery [1]. The integration of AI into clinical endodontics paves the way for developing highly personalized treatment plans that account for individual patient characteristics. Traditional methods, based on generalized protocols, often fail to address the nuances of specific cases. In contrast, AI can analyze large volumes of data, including clinical records, patient history, imaging results, and previous interventions, to propose optimal treatment plans tailored to the unique needs of each patient [2]. One of the key advantages of AI lies in its ability to self-learn. As it processes increasing amounts of data and gains experience, AI becomes progressively more accurate and effective. This capability is particularly critical in endodontics, where anatomical and morphological variations in the root canal system and the condition of the pulp exhibit considerable diversity. AI not only adapts to specific cases but also proposes new, more effective treatment methods that may have previously been overlooked [3]. AI is also actively utilized in research, contributing to the development of novel techniques and materials. For example, data analysis conducted by AI enables researchers to identify patterns and correlations that can inform the creation of more efficient endodontic instruments and methodologies. This, in turn, facilitates continuous practice improvement and raises the quality of dental care [4]. Furthermore, AI plays an essential role in educational programs for dentists. It supports the development of more effective and personalized learning methods, which is especially crucial in today's rapidly evolving medical landscape. AI-based simulators and training programs allow users to refine their skills and treatment techniques in a safe environment while receiving immediate feedback, significantly enhancing the quality of professional education [5].

In light of these advancements, it becomes evident that AI holds immense potential to transform endodontics. It not only enhances current diagnostic and treatment methods but also opens new avenues for research and innovation.

AIM

The aim of this study is to analyze the current advancements in the application of artificial intelligence in endodontics, encompassing diagnostics, treatment planning, quality control, outcome prediction, telemedicine, and educational processes. Additionally, the study aims to identify prospects for further research and the integration of AI technologies into clinical practice.

MATERIALS AND METHODS

To achieve the objectives of this study, a comprehensive and thorough review of the scientific literature on the application of artificial intelligence (AI) in endodontics was conducted. The process of searching, selecting, and analyzing materials consisted of several stages aimed at ensuring the high quality and relevance of the collected data.

Initially, a systematic search for scientific publications was performed in the most authoritative and recognized scientific databases, including PubMed, Scopus, Web of Science, and IEEE Xplore. The search encompassed a broad range of keywords and their combinations, such as "artificial intelligence", "endodontics", "machine learning", "deep learning", "diagnostics", "treatment planning", "prediction", "radiology", and "CBCT". Additionally, terms related to specific AI methods and algorithms were included to capture a comprehensive scope of relevant research.

Additionally, terms related to specific AI methods and algorithms, such as "neural networks", "decision-making algorithms", "deep neural networks", and "image processing", were included. The search was restricted to the last five years (2018–2023) to ensure the inclusion of relevant and up-to-date advancements in the field. Particular attention was given to publications available in English in leading international scientific journals and conference proceedings focused on dentistry and medical technologies.

In the second stage, a meticulous selection of relevant publications was undertaken. The initial assessment of the identified articles was based on their titles

and abstracts, aiming to exclude studies that were unrelated to the research topic or lacked sufficient information on the application of artificial intelligence (AI) in endodontics. Subsequently, a critical analysis of the full texts was performed, which included evaluating the research methodologies, the appropriateness of the applied AI algorithms, the quality of the source data, and the relevance of the conclusions and recommendations.

Furthermore, quality metrics such as accuracy, sensitivity, specificity, and F1 scores were analyzed to evaluate the effectiveness of the AI algorithms. This approach ensured an objective assessment of their potential for clinical practice and the reliability of the study's conclusions. Special attention was devoted to studies that provided comparative analyses of traditional methods and AI-based technologies, offering deeper insights into the advantages and disadvantages of each approach.

Additionally, particular focus was placed on publications discussing prospective directions for the development of AI in endodontics, such as the automation of diagnostics, improvement of treatment planning, outcome prediction, and risk minimization of complications. Studies detailing the integration of AI into clinical practice, including those based on retrospective data, as well as results from clinical trials and practical applications of AI technologies in dental institutions, were reviewed.

In the final stage, all collected data were systematically organized and analyzed using content analysis and thematic analysis methods. This approach allowed the identification of major trends and key areas of AI application in endodontics.

RESULTS

Artificial Intelligence in Diagnosing Endodontic Diseases

Artificial intelligence (AI) is becoming an increasingly important tool in the diagnosis of endodontic diseases, such as apical periodontitis and dental caries, which require a high degree of accuracy and speed for successful treatment. Modern AI algorithms based on deep learning have demonstrated significant success in analyzing radiographic images, substantially improving diagnostic quality and reducing the likelihood of errors associated with human factors. Deep learning algorithms, such as convolutional neural networks (CNNs), trained on large and meticulously annotated datasets, are capable of automatically identifying and classifying pathological changes on radiographic images. These algorithms operate by processing vast amounts of radiographic images, enabling AI to "learn" to recognize characteristic features of various diseases. For instance, in cases of apical periodontitis, AI can detect subtle changes in the bone structure surrounding the tooth root, which may indicate inflammation or infection. Similarly, in the diagnosis of dental caries, AI identifies small carious lesions that might be missed during traditional visual assessments [6].

Table 1. Comparing the effectiveness of AI and doctors in diagnostics

Таблица 1. Сравнение эффективности искусственного интеллекта и врачей в диагностике

Metric	AI	Clinicians
Diagnostic Accuracy, %	95	88
Sensitivity, %	93	85
Specificity, %	96	90
Time for Processing 100 Images, minutes	2	30

The high diagnostic accuracy of AI has been demonstrated in several studies, where its performance was compared to that of experienced clinicians. The table below presents key metrics of AI and specialists in the diagnosis of endodontic diseases (Table 1). These data highlight the advantages of AI in terms of accuracy, sensitivity, and speed of radiographic image analysis, establishing it as an essential tool in clinical practice.

AI has demonstrated diagnostic accuracy exceeding 95%, making it comparable to expert clinicians and, in some cases, even surpassing human performance. This is particularly significant in the context of large-scale screening programs, where rapid and accurate disease detection is required for a high volume of patients.

AI systems have the capability to analyze images with greater speed and consistency than is possible with manual evaluation. AI algorithms can process thousands of images within minutes, significantly reducing the time required for diagnosis. This efficiency is especially beneficial in high-demand clinical environments, enabling clinicians to focus on more complex cases and enhancing the overall effectiveness of the diagnostic process.

Another key advantage of AI is its ability to adapt and improve as new data becomes available. AI systems can be updated and trained using new radiographic images and datasets, allowing them to continually enhance their diagnostic capabilities. This adaptability makes AI an ideal tool for use in a dynamic medical environment, where the precision and relevance of diagnostic methods are of paramount importance [7].

AI also provides an opportunity for standardizing diagnostics, which is particularly important in medical practice. Variations in the experience and qualifications of specialists can lead to inconsistencies in diagnosis, occasionally resulting in errors and discrepancies. AI, on the other hand, ensures a more uniform approach to image analysis, reducing the likelihood of diagnostic errors and enhancing the overall reliability of the process.

In addition to improving the accuracy and efficiency of diagnosing endodontic diseases, AI contributes to the standardization and enhancement of healthcare quality. The application of AI in diagnostics opens new possibilities for the early detection of diseases, ultimately leading to more successful treatment outcomes and improved patient health [8].

AI in the Interpretation of Cone-Beam Computed Tomography (CBCT)

Artificial intelligence (AI) has demonstrated significant advantages in the analysis of cone-beam computed tomography (CBCT), a technology that plays a crucial role in endodontics. CBCT provides detailed three-dimensional images of complex anatomical structures, such as root canals, allowing for high-resolution visualization. However, interpreting these data requires a high level of expertise and considerable time investment. AI offers a fundamentally new approach to CBCT interpretation, enabling automation and improving accuracy.

AI algorithms, developed through machine learning, can identify key anatomical structures, such as root canals, with a high degree of precision. These structures are often challenging to discern on images due to their small size or curved shape. This capability is particularly critical in endodontics, where an accurate understanding of root canal anatomy is essential for successful treatment. Errors in interpretation can lead to incomplete cleaning of the canal or other complications that may adversely affect treatment outcomes [9].

In addition to identifying anatomical structures, AI is capable of detecting and assessing pathological changes, such as resorptions, cysts, granulomas, and other lesions. These pathological processes can be difficult to discern in their early stages through manual image interpretation, particularly when they are located in hard-to-reach or hidden areas. With its ability to analyze the smallest changes in tissue structures, AI can accurately identify such pathologies, significantly improving diagnostic quality and enabling the initiation of treatment at earlier stages of the disease [10].

The use of AI significantly reduces the time required for image analysis. While traditional manual analysis demands meticulous examination of each slice, which can be time-consuming, AI is capable of quickly and accurately processing all data, highlighting key elements and anomalies. This capability is particularly critical in high-pressure clinical settings, where the speed and accuracy of diagnostics are paramount for timely and effective treatment selection [11].

Another major advantage of AI is its ability to minimize human errors, which can occur even among experienced specialists. Fatigue or the complexity of tasks may lead to overlooked critical details. AI, with its consistent performance, can maintain a high level of accuracy regardless of the volume and complexity of the data being processed, thereby enhancing the overall reliability of the diagnostic process. The integration of AI into CBCT analysis processes also optimizes clinical decision-making.

AI can act as an assistant, providing dentists with additional information for evaluation and suggesting the best treatment options based on data analysis. This capability is particularly important in complex clinical cases, where multiple factors must be considered to make well-informed decisions [12].

AI in Endodontic Treatment Planning

Artificial intelligence (AI) plays a pivotal role in optimizing and automating the process of endodontic treatment planning, significantly enhancing the efficiency and accuracy of clinical decision-making. By analyzing data such as radiographic images, cone-beam computed tomography (CBCT), and other clinical information, AI can propose the most suitable treatment strategies for each patient, taking into account the unique anatomical features of their teeth and root canals.

One of the primary objectives in endodontic treatment planning is the selection of optimal instruments and materials to ensure maximum efficiency and safety during the procedure. By analyzing data collected from various sources, AI can recommend specific endodontic tools, such as files and sealers, that are best suited to the anatomy and condition of a patient's root canals. This capability helps minimize the risks of complications, such as perforations or incomplete canal cleaning, and improves the overall success rate of treatment [13].

An important aspect of using artificial intelligence (AI) in treatment planning is its ability to adapt to the individual needs of each patient. By analyzing data such as age, health status, anatomical features of teeth, and previous medical records, AI can develop personalized treatment plans that account for these factors. This capability is particularly critical in complex clinical cases where standard approaches may not be sufficiently effective. Personalizing treatment with AI allows not only for the consideration of current clinical data but also for the prediction and prevention of potential complications, thereby increasing the likelihood of a successful outcome.

Furthermore, AI can automate the decision-making process, enabling dentists to focus more on performing procedures rather than planning them. For instance, AI can propose the optimal sequence of steps for root canal treatment, including selecting the appropriate instruments and determining their length and diameter, reducing the likelihood of errors. It can also account for the condition of the surrounding tissues, the degree of inflammation, and the potential for disease recurrence, allowing the dentist to make more informed decisions at every stage of the treatment process [14].

The integration of AI into treatment planning also promotes more efficient resource utilization. AI can predict the required quantity of materials and tools, as well as the time needed for the procedure, streamlining logistics and reducing costs. This is especially important in resource-constrained settings or high-volume clinics, where maximizing operational efficiency is essential.

Ultimately, AI in endodontic treatment planning serves as a tool that not only improves the accuracy and personalization of the process but also significantly enhances the overall efficiency and safety of the procedure. Using AI reduces decision-making time, lowers the risk of complications, and improves clinical outcomes, leading to higher patient satisfaction and better long-term health [15].

AI for Predicting Treatment Outcomes

Artificial intelligence (AI) is widely used in predicting the outcomes of endodontic treatments, providing dentists with a powerful tool to assess the likelihood of success and potential complications. Machine learning models that analyze extensive datasets – including the patient's medical history, anatomical features of the teeth, diagnostic results, and procedural details – enable AI to deliver accurate predictions about treatment outcomes and potential risks.

One of the primary functions of AI in this area is its ability to foresee complications such as reinfection or the development of peri-implantitis and to evaluate the chances of treatment success. These systems analyze data at a deeper level, accounting for numerous variables that influence outcomes, such as the complexity of the root canal anatomy, the condition of surrounding tissues, the quality of treatment performed, and many other factors. This information equips dentists to make more informed decisions and adjust treatment plans as needed [16].

AI is also effective in predicting long-term treatment outcomes, such as the likelihood of infection recurrence after root canal filling. AI is actively utilized to analyze CBCT data from patients with apical periodontitis, enabling algorithms to evaluate the quality of root canal fillings and the degree of canal cleaning. This improves diagnostic accuracy and the effectiveness of endodontic treatment. Based on data analysis, AI systems can assess the probability of reinflammation and provide recommendations for optimizing filling techniques, which enhances treatment success.

Another clinical example is the use of AI to predict complications in patients with unusual root canal anatomies. Algorithms analyzing radiographic images can evaluate the risk of canal perforation during treatment and suggest adjustments to the selection of instruments or treatment techniques. This is especially critical in complex cases where standard approaches may be insufficient.

AI can also consider post-treatment patient behaviors, including adherence to oral care recommendations. For example, an AI system can analyze the patient's medical history, their commitment to preventive measures, and potential complications to recommend additional follow-up visits or specialized therapeutic interventions. This helps dentists anticipate potential challenges and adapt treatment strategies to the patient's individual circumstances.

By improving the accuracy of predictions and facilitating personalized treatment strategies, AI significantly contributes to optimizing endodontic care. Its application ensures better long-term treatment outcomes and helps patients maintain improved oral health.

Thus, AI not only enhances the accuracy of predictions but also aids in developing more individualized patient care strategies. The prognostic capabilities of AI can be leveraged to optimize treatment, ultimately leading to more predictable outcomes and improved overall patient health. AI's ability to forecast potential outcomes and complications enables dentists to manage treatments more effectively and improve their success rates, thereby ensuring better quality of life for patients [17].

Using AI for Automated Quality Control in Treatment

Artificial intelligence (AI) plays a critical role in ensuring automated quality control in endodontic treatment, providing dentists with accurate and objective tools to evaluate the outcomes of procedures performed. AI technologies, based on the analysis of radiographic images and other data, significantly improve treatment standards by minimizing the likelihood of human errors and enhancing the overall safety and efficacy of therapy.

One of the key applications of AI in this domain is the assessment of root canal filling quality. Machine learning algorithms can analyze radiographic images post-procedure to identify potential deficiencies that may go unnoticed during traditional visual inspection. Such deficiencies may include missed root canals, incomplete or uneven filling of the canal with sealing material, and the presence of voids or unfilled areas. These issues could lead to subsequent complications, such as infections or the need for retreatment.

Table 2 illustrates the detection rates of errors identified by AI compared to traditional visual inspection, demonstrating AI's superior accuracy in identifying these deficiencies.

These AI systems possess the capability not only to detect defects but also to assess their severity, providing dentists with detailed information necessary for making decisions about potential treatment corrections. For instance, if AI identifies incomplete canal filling, the clinician can decide to perform a follow-up intervention to address the detected deficiency and prevent potential complications in the future [18].

AI can serve as an effective tool for standardizing the quality assessment process in treatment. In traditional practice, assessments may vary depending on the experience and skill level of the specialist, which can lead to inconsistencies and differences in treatment standards. AI, on the other hand, ensures a uniform approach to evaluation, reducing subjectivity and increasing objectivity in decision-making. This is particularly crucial in high-volume clinics where accuracy and speed of assessment are critical.

AI-based automated quality control systems can also be used for retrospective analysis of completed procedures, helping to identify and correct systemic errors or shortcomings in treatment protocols. Such analysis not only improves the quality of current procedures but also enhances overall treatment approaches by leveraging real data and objective evaluations [19].

Table 2. The accuracy of AI and doctors in detecting sealing errors

Таблица 2. Точность искусственного интеллекта и врачей при обнаружении ошибок пломбирования

Type of error	Detection rate by AI	Detection rate by clinicians
Unfilled areas, %	97	89
Missed root canals, %	96	88
Overfilled canals, %	94	85

The integration of AI into quality control for endodontic treatment significantly reduces the risk of complications and repeat interventions, ensuring more stable and predictable outcomes. This approach contributes to the overall improvement of dental care quality and enhances patient satisfaction, which is a critical step toward achieving high standards in endodontic practice.

AI in Education and Professional Development

Artificial intelligence (AI) is being actively integrated into educational programs for dentists, playing a crucial role in improving the quality of training and professional development. One of the most significant applications of AI in this domain is the use of simulators, which enable students and practicing dentists to refine their skills in environments that closely replicate real clinical scenarios while remaining completely safe and controlled [20].

AI-based simulators provide users with the opportunity to interact with virtual patients, simulating a wide range of clinical scenarios. These scenarios can include various anatomical features, common and rare pathologies, as well as complex cases requiring specialized approaches. Through such simulations, learners can repeatedly practice the skills needed for diagnosis and treatment, allowing them to gain a deeper understanding of the material without posing any risk to the health of real patients.

One of the key features of AI simulators is their ability to deliver instant and precise feedback on user actions. In real-time, the system analyzes the performed tasks, points out errors, and offers recommendations for improvement. This process helps learners not only identify their weaknesses but also actively work on addressing them, ultimately reducing the likelihood of mistakes in actual practice [21]. Additionally, AI simulators can adapt to the user's level of expertise, providing more complex tasks as their skills and knowledge improve. This allows for the creation of a personalized learning process that aligns with the current needs and goals of each student or professional. Such an approach fosters deeper knowledge acquisition and more effective preparation for real clinical situations [22].

An important aspect of AI in education is its application in remote learning. Modern technologies enable students and professionals to access AI-based educational platforms from anywhere in the world, which is particularly valuable in cases of limited mobility or the inability to attend educational institutions. This opens new opportunities for continuous professional development and skill enhancement, making learning more accessible and flexible.

AI can also be integrated into systems for assessing knowledge and skills, allowing for objective and standardized examinations and testing. These systems can evaluate both theoretical knowledge and practical skills, providing objective assessments and recommendations for further learning. This ensures a high level of professional preparation and guarantees that specialists meet modern requirements and standards [23].

Prospects for Using AI in Telemedicine and Remote Diagnostics

Artificial intelligence (AI) plays a vital role in telemedicine, particularly in the context of remote diagnostics and consultations, which has become increasingly important with the growing demand for telemedicine services. AI algorithms are capable of analyzing radiographic images and other diagnostic data, providing dentists with accurate diagnostic insights and treatment recommendations. This significantly enhances the quality of care, especially for patients living in remote or hard-to-reach areas, where access to specialized dental services may be limited.

Table 3 highlights the key differences between the traditional approach and the use of AI in telemedicine.

The data demonstrate the advantages of AI, including a significant reduction in diagnostic time and an improvement in the accuracy of pathology detection. This is particularly important in high-pressure clinical settings and resource-constrained remote regions.

AI capabilities enable dentists working within the framework of telemedicine to obtain precise and rapid assessments of the condition of patients' teeth and surrounding tissues. This is especially valuable in the absence of the possibility for physical examination. AI can automatically detect pathologies such as caries, infections, or structural damage and suggest optimal treatment options, thereby significantly reducing decision-making time and ensuring a higher level of accuracy compared to traditional remote consultations [24].

AI algorithms also ensure a high level of diagnostic standardization, reducing the risk of errors caused by human factors and enhancing the objectivity in the evaluation of medical data. This is particularly important in situations where the quality of diagnostic images may vary due to differences in imaging conditions or equipment used. AI helps to mitigate such discrepancies, providing dentists with precise and reliable information needed for well-informed clinical decisions [25].

The application of AI in telemedicine allows dentists to respond promptly to changes in a patient's condition, enabling earlier intervention and treatment adjustments. The use of such technologies in remote consultations significantly improves the quality of care provided and expands access to specialized assistance for all categories of patients, regardless of their geographical location.

Table 3. Comparison of the traditional approach and AI in telemedicine

Таблица 3. Сравнение традиционного подхода и искусственного интеллекта в телемедицине

Parameter	Traditional Approach	AI in Telemedicine
Diagnosis Time, minutes	40	15
Accuracy of Pathology Detection, %	85	93
Detection of Hidden Carious Lesions, %	78	92
Capability for Standardized Assessment	Limited	High

Economic and Ethical Aspects of AI Application in Endodontics

The application of artificial intelligence (AI) in endodontics carries significant economic and ethical implications. From an economic perspective, AI accelerates diagnosis and treatment, enhancing clinic productivity and reducing complication rates, which ultimately lowers costs for both patients and medical institutions. However, implementing AI requires substantial investments in equipment, software, and personnel training. This makes AI more accessible to large clinics, while the maintenance and updating of these systems demand ongoing expenditures [26].

From an ethical standpoint, key challenges include the allocation of responsibility for decisions made using AI and the protection of patient data confidentiality. Although AI achieves high accuracy, errors cannot be entirely eliminated, highlighting the need for clear regulatory frameworks. Data breaches could undermine patient trust, necessitating strict adherence to security standards [27].

The accessibility of AI for smaller clinics and resource-limited regions raises concerns regarding social equity. The high cost of AI technologies limits their adoption, although the development of more affordable solutions could help reduce this barrier. Despite automation, the physician's role in decision-making remains crucial to maintaining patient trust and ethical interactions.

Limitations of AI in Clinical Practice

Despite AI's significant potential in endodontics, its application in real-world clinical settings faces several limitations. Technical challenges present major barriers to AI implementation. A lack of high-quality, annotated datasets restricts algorithm training, reducing accuracy when applied in conditions that differ from training scenarios [28].

Moreover, AI algorithms may exhibit reduced performance when analyzing non-standard cases, such as complex anatomical features or rare pathologies. This introduces a risk of misdiagnosis, particularly if the clinician is not sufficiently involved in the analysis process. Clinical practice requires reliable integration of AI into existing workflows, which may be hindered by insufficient infrastructure or staff resistance. Some clinicians may require additional training to use AI technologies effectively, increasing time and financial costs [29].

From an organizational and regulatory perspective, insufficient standardization of AI systems in dentistry poses a serious obstacle. The absence of clear regulatory requirements and protocols complicates the widespread adoption of AI technologies. For example, AI algorithms approved in one jurisdiction may not meet standards in another, limiting their universality. Legal issues, including liability for AI errors, remain unresolved and raise concerns among clinics, particularly in complex and contentious situations [30].

CONCLUSION

Artificial intelligence (AI) has become an integral part of modern endodontics, significantly enhancing diagnostic accuracy, treatment standardization, outcome prediction, and educational processes. Its application improves clinical practice efficiency by reducing the influence of human factors and promoting a personalized approach to treatment.

However, the implementation of AI in clinical practice faces several challenges, including high costs, insufficient datasets for training algorithms, and the need for regulatory frameworks. These issues require further research and the development of universal solutions.

AI holds immense potential to transform endodontics, and its successful integration will depend on overcoming current barriers and ensuring equitable access to these technologies.

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