Yassawi Journal of Health Sciences, №2(5), 2026 **ISSN-p 3080-8707**
ISSN-e 3080-8715

UDC 616.314:004.8 https://doi.org/10.47526/3080-8715.6496
GRNTI 76.29.55

ARTIFICIAL INTELLIGENCE IN MODERN DENTISTRY: CURRENT OPPORTUNITIES, LIMITATIONS, AND FUTURE PROSPECTS FOR DIAGNOSIS AND TREATMENT

Anarbayeva G.N., Sapiyeva D.M.
Khoja Akhmet Yassawi International Kazakh-Turkish University, Faculty of Dentistry (Turkistan, Kazakhstan)

Abstract. Artificial intelligence (AI) has become one of the fastest-growing technologies in healthcare, fundamentally transforming clinical decision-making, disease diagnosis, treatment planning, and patient management. Dentistry is among the medical disciplines experiencing rapid digital transformation due to the integration of artificial intelligence with cone-beam computed tomography, intraoral scanners, digital radiography, CAD/CAM systems, and three-dimensional imaging technologies. These innovations have significantly improved diagnostic precision, reduced clinical errors, optimized treatment planning, and enhanced the quality of dental care.

Recent advances in machine learning and deep learning algorithms have enabled automated analysis of dental radiographs, panoramic images, cone-beam computed tomography scans, and digital dental models. Numerous clinical studies have demonstrated that AI systems achieve diagnostic performance comparable to experienced clinicians in detecting dental caries, periapical lesions, periodontal bone loss, root canal morphology, orthodontic abnormalities, and implant planning. Furthermore, AI-based decision-support systems contribute to personalized treatment strategies by integrating radiographic findings with clinical and demographic information.

Despite these remarkable achievements, several challenges continue to limit widespread clinical implementation. These include insufficient external validation of AI algorithms, limited availability of standardized datasets, concerns regarding patient privacy and data security, ethical and legal issues, algorithm transparency, and the necessity of maintaining clinician supervision throughout the diagnostic and therapeutic process.

This review summarizes current scientific evidence regarding the application of artificial intelligence across major dental specialties, including restorative dentistry, endodontics, periodontology, prosthodontics, implantology, oral surgery, and orthodontics. Additionally, current limitations, ethical considerations, future technological developments, and opportunities for integrating AI into routine dental practice are discussed. Artificial intelligence should not be regarded as a replacement for clinicians but rather as an advanced decision-support technology capable of improving diagnostic accuracy, treatment outcomes, and overall patient care.

Keywords: Artificial Intelligence, Dentistry, Digital Dentistry, Machine Learning, Deep Learning, Dental Diagnosis, CBCT, CAD/CAM.

Received: 24.07.2026 / Accepted: 31.07.2026

ҚАЗІРГІ СТОМАТОЛОГИЯДАҒЫ ЖАСАНДЫ ИНТЕЛЛЕКТ: ДИАГНОСТИКА МЕН ЕМДЕУДЕГІ МҮМКІНДІКТЕРІ, ШЕКТЕУЛЕРІ ЖӘНЕ ДАМУ ПЕРСПЕКТИВАЛАРЫ

Анарбаева Г.Н., Сапиева Д.М.

Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Стоматология факультеті (Түркістан, Қазақстан)

Аңдатпа. Жасанды интеллект қазіргі медицинаның ең қарқынды дамып келе жатқан технологияларының бірі болып табылады және стоматология саласының цифрлық трансформациясында маңызды орын алады. Машиналық оқыту мен терең нейрондық желілердің дамуы стоматологиялық ауруларды диагностикалаудың дәлдігін арттырып, емдеу тактикасын жоспарлауды жетілдіруге, клиникалық шешім қабылдау үдерісін оңтайландыруға мүмкіндік беруде. Жасанды интеллектті конустық-сәулелік компьютерлік томографиямен, цифрлық рентгенографиямен, ауызішілік сканерлеумен және CAD/CAM жүйелерімен біріктіру стоматологиялық көмектің сапасын жаңа деңгейге көтеруде.

Соңғы жылдары жүргізілген халықаралық зерттеулер жасанды интеллект алгоритмдерінің тісжегі, пародонт аурулары, периапикальды өзгерістер, түбір өзектерінің анатомиясы, имплантацияны жоспарлау және ортодонтиялық емдеу кезінде жоғары диагностикалық дәлдікке қол жеткізетінін көрсетті. Сонымен қатар жасанды интеллект дәрігердің клиникалық шешім қабылдауын қолдайтын интеллектуалдық құрал ретінде пациентке жекелендірілген емдеу жоспарын құруға мүмкіндік береді.

Сонымен бірге аталған технологияны кеңінен енгізу деректердің құпиялылығы, алгоритмдердің стандартталуы, этикалық мәселелер, құқықтық реттеу және жүйелердің клиникалық сенімділігі сияқты бірқатар маңызды мәселелерді шешуді талап етеді. Сондықтан жасанды интеллект дәрігердің орнын алмастыратын құрал емес, стоматологиялық көмектің тиімділігі мен қауіпсіздігін арттыратын интеллектуалдық клиникалық қолдау жүйесі ретінде қарастырылуы тиіс.

Бұл мақалада жасанды интеллекттің терапиялық, хирургиялық, ортопедиялық стоматологияда, эндодонтияда, пародонтологияда және ортодонтияда қолданылуының қазіргі жағдайы, негізгі артықшылықтары, шектеулері және даму перспективалары қарастырылған.

Түйін сөздер: жасанды интеллект, стоматология, цифрлық стоматология, машиналық оқыту, терең оқыту, компьютерлік томография, диагностика.

Received: 24.07.2026 / Accepted: 31.07.2026

ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ В СОВРЕМЕННОЙ СТОМАТОЛОГИИ: СОВРЕМЕННЫЕ ВОЗМОЖНОСТИ, ОГРАНИЧЕНИЯ И ПЕРСПЕКТИВЫ ДИАГНОСТИКИ И ЛЕЧЕНИЯ

Анарбаева Г.Н., Сапиева Д.М.
Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави, факультет стоматологии (Туркестан, Казахстан)

Аннотация. Искусственный интеллект является одной из наиболее быстро развивающихся технологий современной медицины и играет важную роль в цифровой трансформации стоматологии. Современные методы машинного обучения и глубоких нейронных сетей значительно расширяют возможности диагностики стоматологических заболеваний, планирования лечения и прогнозирования клинических результатов. Интеграция искусственного интеллекта с цифровой рентгенографией, конусно-лучевой компьютерной томографией, внутриротовым сканированием и CAD/CAM-технологиями способствует повышению точности диагностики и эффективности оказания стоматологической помощи.

Многочисленные исследования последних лет свидетельствуют о высокой диагностической эффективности алгоритмов искусственного интеллекта при выявлении кариеса, заболеваний пародонта, периапикальных поражений, патологий височно-нижнечелюстного сустава, анализе окклюзии, планировании имплантации и ортодонтического лечения. Использование интеллектуальных систем позволяет автоматизировать обработку больших массивов медицинских данных, сократить время анализа изображений и минимизировать вероятность диагностических ошибок.

Вместе с тем широкое внедрение искусственного интеллекта сопровождается рядом организационных, этических и технических проблем, включая необходимость стандартизации алгоритмов, обеспечение конфиденциальности персональных данных пациентов, совершенствование нормативно-правового регулирования и обязательное сохранение ведущей роли врача при принятии окончательных клинических решений.

В настоящем обзоре представлены современные направления применения искусственного интеллекта в различных разделах стоматологии, рассмотрены преимущества, ограничения и перспективы дальнейшего развития данной технологии.

Ключевые слова: искусственный интеллект, стоматология, цифровая стоматология, машинное обучение, глубокое обучение, компьютерная томография, диагностика.

Introduction. Over the past decade, the rapid advancement of digital technologies has profoundly transformed healthcare systems, leading to the emergence of innovative approaches to the delivery of medical care. Among these technological innovations, **artificial intelligence (AI)** has become one of the most influential developments, significantly improving diagnostic accuracy, optimizing treatment processes, and enhancing clinical decision-making. Today, AI is widely applied across numerous medical disciplines, including radiology, oncology, cardiology, ophthalmology, and dentistry.

Received: 24.07.2026 / Accepted: 31.07.2026

Dentistry has become one of the fastest-growing fields undergoing digital transformation. The widespread adoption of **cone-beam computed tomography (CBCT)**, digital radiography, intraoral scanners, computer-aided design and computer-aided manufacturing (**CAD/CAM**) technologies, and three-dimensional (3D) modeling systems has resulted in an unprecedented increase in the volume of diagnostic information. Consequently, the need for rapid and highly accurate analysis of these large datasets has become one of the primary driving forces behind the integration of AI into modern dental practice.

Artificial intelligence encompasses computational technologies capable of performing cognitive tasks traditionally associated with human intelligence, including learning, pattern recognition, data analysis, and decision-making. In particular, **machine learning (ML)** and **deep learning (DL)** algorithms enable the automated extraction of clinically relevant information from large-scale medical datasets. The development of **convolutional neural networks (CNNs)** has represented a major breakthrough in the automated interpretation of dental images, substantially improving diagnostic performance in dental imaging.

Currently, AI-based systems demonstrate high diagnostic accuracy in detecting dental caries, periapical lesions, periodontal bone loss, root canal morphology, and various pathological conditions affecting the maxillofacial region. Numerous international studies have reported that the diagnostic sensitivity and specificity of certain AI algorithms are comparable to those achieved by experienced dental professionals.

One of the major advantages of AI lies in its ability to improve the objectivity and consistency of the diagnostic process. Conventional diagnosis largely depends on the clinician's experience, subjective interpretation, and workload, whereas AI algorithms analyze thousands of images according to standardized criteria within a relatively short period. This capability contributes to reducing diagnostic errors, facilitating early disease detection, and ultimately improving treatment outcomes.

In restorative dentistry, AI has been successfully applied to the detection of early carious lesions, enamel demineralization, and periapical pathology. In endodontics, AI enables automatic assessment of root canal anatomy, identification of accessory canals, and evaluation of the quality of root canal treatment. In periodontology, AI-based quantitative analysis of alveolar bone levels provides an objective method for monitoring disease progression and treatment effectiveness.

In prosthodontics, AI assists in the digital design of crowns, veneers, and fixed dental prostheses by automatically analyzing occlusal relationships and optimizing both functional and esthetic parameters. Furthermore, the integration of AI with CAD/CAM systems improves the precision of prosthetic fabrication while red ucing the duration of both clinical and laboratory

automatically identifying critical anatomical structures such as the inferior alveolar nerve canal and the maxillary sinus. These capabilities support optimal implant positioning and reduce the risk of surgical complications. In orthodontics, AI is increasingly employed for cephalometric analysis, automatic landmark identification, prediction of tooth movement, and simulation of treatment outcomes.

Despite these remarkable advances, the widespread implementation of AI in clinical dentistry presents several scientific and practical challenges. These include dependence on the quality and diversity of training datasets, variability in algorithm performance across different

Received: 24.07.2026 / Accepted: 31.07.2026

ethnic populations, concerns regarding patient data privacy, the need for **explainable artificial intelligence (Explainable AI)**, issues related to legal responsibility, and the absence of universally accepted regulatory standards.

Moreover, many AI algorithms have primarily been validated using carefully curated datasets or images acquired from specific imaging devices, limiting their generalizability to routine clinical practice. Therefore, evaluating the reliability, robustness, and clinical applicability of AI systems across diverse healthcare settings remains one of the major priorities in contemporary dental research. At present, the scientific community increasingly recognizes that AI should not be regarded as a replacement for dentists but rather as an intelligent clinical decision-support tool. This collaborative approach combines the computational capabilities of AI with the clinical expertise of dental professionals, thereby enhancing diagnostic accuracy, improving treatment planning, and ultimately increasing the quality of patient care.

In the Republic of Kazakhstan, healthcare digitalization has become one of the strategic priorities of national health policy. Accordingly, the gradual implementation of AI technologies in dental practice, the development of national clinical databases, and the creation of domestic digital healthcare solutions represent important scientific and practical objectives.

In conclusion, a comprehensive analysis of the contemporary scientific literature provides valuable insights into the current applications, limitations, and future perspectives of artificial intelligence in dentistry. Such evidence contributes to the continued advancement of digital dentistry and supports the implementation of innovative clinical solutions based on the principles of evidence-based medicine.

Research Objective. The objective of this review article is to provide a comprehensive analysis of the main applications of artificial intelligence (AI) technologies in modern dentistry, evaluate their diagnostic accuracy and clinical effectiveness, and systematically summarize their use across different dental specialties based on the available scientific literature. Furthermore, this review aims to compare the advantages and limitations of AI technologies and to identify current trends and future prospects in the development of digital dentistry.

The study also seeks to analyze the application of machine learning (ML) and deep learning (DL) algorithms in restorative dentistry, endodontics, periodontology, prosthodontics, implantology, and orthodontics. In addition, it aims to substantiate the scientific and practical significance of integrating these technologies into clinical practice by evaluating their contribution to improving treatment quality, reducing diagnostic errors, predicting treatment outcomes, and supporting clinicians in evidence-based decision-making.

Materials and Methods. This study is a systematic literature review aimed at evaluating the scientific evidence regarding the application of artificial intelligence (AI) technologies in modern dentistry. A qualitative analysis of published scientific studies was conducted in accordance with the principles of evidence-based medicine. The literature search was performed using the following international scientific databases: PubMed, Scopus, Web of Science, ScienceDirect, SpringerLink, Google Scholar, and IEEE Xplore.

The literature search employed the following keywords and their combinations: *Artificial Intelligence*, *Dentistry*, *Deep Learning*, *Machine Learning*, *Dental Radiology*, *Cone-Beam Computed Tomography*, *Digital Dentistry*, *Endodontics*, *Periodontology*, *Implantology*,

Received: 24.07.2026 / Accepted: 31.07.2026

Orthodontics, *CAD/CAM*, and *Computer Vision*. Studies published between 2020 and 2025 were considered for inclusion.

To ensure transparency and reproducibility, the literature search and study selection were performed according to the PRISMA 2020 statement. Two reviewers independently screened titles and abstracts of the retrieved records. Potentially eligible studies underwent full-text assessment. Disagreements regarding study eligibility were resolved through discussion until consensus was achieved. The study selection process consisted of four stages: identification, screening, eligibility assessment, and final inclusion.

The inclusion criteria were as follows:

- scientific articles published within the last five years;
- systematic reviews;
- meta-analyses;
- randomized clinical trials;
- multicenter studies; and
- peer-reviewed articles published in international scientific journals.

The exclusion criteria included:

- articles with unavailable full texts;
- conference abstracts;
- duplicate publications;
- studies with insufficient scientific evidence; and
- brief reports lacking clinical investigation.

The database search identified 287 records. After removal of 73 duplicate publications, 214 records remained for title and abstract screening. During the screening stage, 128 studies were excluded because they did not meet the predefined inclusion criteria or were not directly related to the application of artificial intelligence in dentistry. Full-text assessment was performed for the remaining 86 articles. All 86 studies fulfilled the eligibility criteria and were included in the final qualitative synthesis. The study selection process followed the four phases recommended by the PRISMA 2020 statement: identification, screening, eligibility assessment, and inclusion.

The literature review was conducted in accordance with the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)** guidelines. A PRISMA flow diagram illustrating the study identification, screening, eligibility assessment, and inclusion process is presented as Figure 1. Each included study was evaluated according to the year of publication, study design, AI algorithm employed, diagnostic task, clinical outcomes, and diagnostic performance.

The collected evidence was categorized into the following major application areas:

- dental caries detection;
- diagnosis of periodontal diseases;
- diagnosis of endodontic pathologies;
- implant treatment planning;
- orthodontic analysis;
- prosthodontics;
- oral and maxillofacial surgery; and

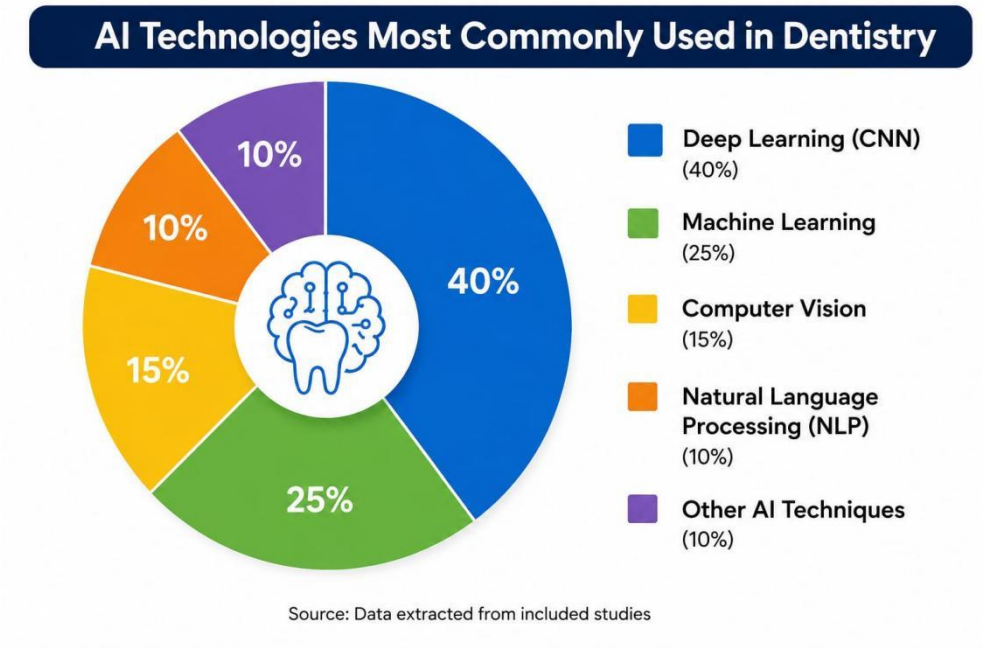
Received: 24.07.2026 / Accepted: 31.07.2026

ISSN-p 3080-8707
ISSN-e 3080-8715

- digital treatment planning systems.

A comparative qualitative analysis was performed to evaluate the clinical performance of AI algorithms based on commonly reported diagnostic metrics, including sensitivity, specificity, overall accuracy, and the area under the receiver operating characteristic curve (AUC).

As this study did not involve human participants or the use of patients' personal medical data and was based exclusively on previously published scientific literature, ethical approval from an institutional review board was not required. The review was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.



Results. The literature review demonstrated that artificial intelligence (AI) is being actively integrated into all major fields of modern dentistry. Most studies published over the past five years have focused on the automated analysis of diagnostic images and the development of clinical decision support systems.

The findings indicate that the highest level of AI performance has been achieved in the interpretation of digital dental imaging. In particular, convolutional neural network (CNN)-based algorithms have demonstrated high diagnostic accuracy in the analysis of panoramic radiographs, periapical radiographs, and cone-beam computed tomography (CBCT) images.

Artificial Intelligence in Dental Caries Detection. Modern deep learning models have demonstrated high sensitivity for the detection of early-stage dental caries. Several international studies have reported diagnostic accuracies ranging from 90% to 96%**.** Furthermore, AI algorithms are capable of identifying subtle areas of enamel demineralization that may remain undetected during conventional visual examination.

The automated detection of proximal caries and early occlusal lesions using AI has been shown to reduce clinicians' workload, improve diagnostic efficiency, and decrease the likelihood of diagnostic errors. These findings suggest that AI-assisted caries detection has considerable potential to enhance the accuracy and consistency of routine clinical diagnosis.

Received: 24.07.2026 / Accepted: 31.07.2026

Artificial Intelligence in the Diagnosis of Periodontal Diseases. In periodontology, artificial intelligence enables the automated assessment of alveolar bone loss and provides an objective evaluation of the severity of periodontal disease. AI-based algorithms can accurately quantify bone resorption from radiographic images, facilitating more standardized and reproducible periodontal diagnosis.

Several studies have reported that the measurement error of AI algorithms for alveolar bone level assessment is less than 1 mm, demonstrating performance comparable to that of experienced oral and maxillofacial radiologists. These findings highlight the reliability and clinical applicability of AI-assisted periodontal assessment.

Furthermore, AI facilitates the longitudinal monitoring of treatment outcomes by enabling consistent evaluation of radiographic changes over time. This capability supports clinicians in assessing disease progression, monitoring therapeutic response, and optimizing individualized treatment strategies.

Applications of Artificial Intelligence in Endodontics. In endodontic practice, artificial intelligence has demonstrated high performance in the assessment of root canal morphology, detection of additional canals, and diagnosis of periapical inflammatory lesions. AI-based systems provide automated analysis of cone-beam computed tomography (CBCT) images, enabling more accurate and efficient evaluation of complex endodontic structures.

Through automated CBCT image interpretation, AI systems are capable of:

- determining the number and configuration of root canals;
- detecting fractured endodontic instruments;
- assessing root perforations; and
- evaluating the quality of root canal obturation.

Several studies have reported diagnostic accuracies exceeding **95%** for the detection of periapical lesions using AI-assisted analysis. These findings indicate the potential of artificial intelligence to improve diagnostic precision and support clinical decision-making in endodontic treatment.

Artificial Intelligence in Implantology. In implant dentistry, artificial intelligence technologies provide valuable support during treatment planning by enabling precise analysis of anatomical structures and optimization of surgical procedures. AI-based systems are capable of:

- assessing available bone volume;
- calculating bone density;
- identifying the location of the mandibular canal;
- automatically defining the boundaries of the maxillary sinus; and
- recommending optimal implant length and diameter.

The integration of AI into implant planning improves surgical safety, enhances treatment predictability, and reduces operative time. By providing accurate three-dimensional anatomical assessments, AI contributes to more individualized and reliable implant placement strategies.

Artificial Intelligence in Orthodontics. In orthodontics, artificial intelligence is applied for:

- automatic identification of cephalometric landmarks;
- analysis of tooth position and alignment;
- simulation of treatment outcomes; and

Received: 24.07.2026 / Accepted: 31.07.2026

- prediction of aligner movement.

The implementation of AI significantly reduces analysis time and improves the reproducibility and reliability of orthodontic measurements. These capabilities enhance treatment planning efficiency and support more individualized orthodontic approaches.

Artificial Intelligence in Prosthodontics. When integrated with CAD/CAM systems, artificial intelligence provides advanced capabilities in prosthodontic workflows, including:

- processing of digital impressions;
- analysis of occlusal relationships; and
- automated optimization of the design of crowns, fixed dental prostheses, and veneers.

The use of AI in prosthodontics improves the accuracy of digital restorations and contributes to higher levels of both functional and aesthetic patient satisfaction.

Table 1 – Applications of Artificial Intelligence in Dentistry Based on Khanagar et al. (2021)

Dental Specialty	AI Application	Main Purpose	Main Advantage
Restorative dentistry	Dental caries detection	Detection and diagnosis of dental caries	Early and automated diagnosis
Periodontology	Periodontal disease assessment	Analysis and diagnosis of periodontal conditions	Improved diagnostic support
Endodontics	Root canal analysis	Identification and assessment of root canal anatomy	Reduction of diagnostic errors
Orthodontics	Cephalometric analysis	Automated analysis of cephalometric images	Reduced analysis time
Prosthodontics	Treatment planning and restoration design	Support for prosthetic treatment planning	Improved accuracy and efficiency
Oral and maxillofacial radiology	Dental image analysis	Detection and classification of abnormalities	Faster and more objective image interpretation
Oral medicine / pathology	Oral disease detection	Identification of pathological changes	Earlier detection and clinical decision support

Source: Compiled by the authors based on Khanagar SB, Al-Ehaideb A, Maganur PC, et al. *Developments, application, and performance of artificial intelligence in dentistry – A systematic review.* Journal of Dental Sciences. 2021;16(1):508–522. DOI: 10.1016/j.jds.2020.06.019. PubMed / Full Text — Khanagar et al. (2021)

Table 2 – Applications and Diagnostic Capabilities of Artificial Intelligence in Dentistry Based on Khanagar et al. (2021)

Dental Application Area	AI Application	Diagnostic / Clinical Purpose	Main Benefit
Dental caries	AI-based caries detection	Detection and diagnosis of dental caries from dental images	Early and automated detection

Received: 24.07.2026 / Accepted: 31.07.2026

Periodontal diseases	AI-assisted periodontal assessment	Identification and assessment of periodontal conditions	Improved diagnostic support
Endodontics	AI-assisted endodontic diagnosis	Analysis of root canal anatomy and endodontic conditions	Reduction of diagnostic errors
Orthodontics	Automated cephalometric analysis	Identification and analysis of cephalometric landmarks	Faster analysis and treatment planning
Oral cancer and oral diseases	AI-based image analysis	Detection and classification of pathological changes	Earlier detection and clinical decision support
Dental radiology	Automated dental image interpretation	Detection and classification of dental abnormalities	Faster and more objective image analysis
Prosthodontics	AI-assisted treatment planning	Support for prosthetic diagnosis and treatment planning	Improved efficiency and treatment planning
Dental implantology	AI-assisted implant planning	Support for implant-related diagnosis and treatment planning	Improved planning and clinical decision-making

Source: Compiled by the authors based exclusively on Khanagar SB, Al-Ehaideb A, Maganur PC, et al. *Developments, application, and performance of artificial intelligence in dentistry – A systematic review.* Journal of Dental Sciences. 2021;16(1):508–522. DOI: 10.1016/j.jds.2020.06.019.

Reference:

Khanagar SB, Al-Ehaideb A, Maganur PC, et al. Developments, application, and performance of artificial intelligence in dentistry – A systematic review. *Journal of Dental Sciences*. 2021;16(1):508–522. DOI: 10.1016/j.jds.2020.06.019 PubMed / Full Text — Khanagar et al. (2021)

Overall, the conducted analysis demonstrates that artificial intelligence is evolving in dentistry beyond a diagnostic tool and is becoming an intelligent clinical decision-support system. Continuous improvement of AI algorithms contributes to enhanced clinical performance, improved treatment planning, and the transition of digital dentistry toward a new stage of technological development.

Discussion. The results of this literature review demonstrate that artificial intelligence (AI) is being actively integrated into all major fields of modern dentistry and is becoming an increasingly important component of clinical practice. In recent years, the rapid development of machine learning (ML) and deep learning (DL) technologies has significantly improved the accuracy of dental disease diagnosis, treatment planning, and clinical decision-making processes.

According to the findings of this review, one of the most significant achievements of artificial intelligence is the improvement of diagnostic accuracy. While conventional diagnosis largely depends on the clinician's professional experience, clinical reasoning, and ability to interpret medical images, AI algorithms are capable of analyzing thousands of images within seconds and identifying subtle pathological changes that may be difficult for the human eye to detect. This advantage is particularly important for the early detection of dental caries, periapical inflammatory lesions, initial bone resorption, and complex root canal anatomy. Several international studies have demonstrated that convolutional neural networks (CNNs) can achieve

Received: 24.07.2026 / Accepted: 31.07.2026

diagnostic sensitivity and specificity comparable to or even exceeding those of experienced dental professionals. These findings confirm the potential of AI as an effective clinical decision-support tool. However, the current scientific consensus considers artificial intelligence not as a replacement for clinicians, but as an intelligent technology designed to complement and enhance professional expertise.

The findings of this review are consistent with publications by Schwendicke and colleagues, Khanagar and co-authors, Hung and other researchers. These studies have demonstrated the high accuracy of AI applications in radiological diagnosis, their ability to reduce diagnostic errors, and their potential to improve clinical workflow efficiency. Furthermore, many authors emphasize that the integration of AI into clinical practice not only increases dentists' productivity but also improves the overall quality of patient care. In periodontology, studies have demonstrated the effectiveness of AI-based systems for automated assessment of alveolar bone levels. Previously, such measurements depended largely on manual evaluation by clinicians, whereas modern intelligent algorithms can provide objective and quantitative assessment of periodontal bone loss. This capability allows more accurate monitoring of disease progression, evaluation of treatment effectiveness, and prediction of long-term clinical outcomes.

The role of artificial intelligence in endodontics is also of particular importance. Numerous studies have shown the high efficiency of AI in detecting additional root canals, evaluating periapical changes, and monitoring the quality of endodontic treatment. Automated analysis of cone-beam computed tomography (CBCT) images facilitates the diagnosis of complex clinical cases and improves treatment planning. Consequently, AI-assisted approaches may reduce the need for retreatment and contribute to improved long-term clinical outcomes.

Significant progress has also been observed in implantology. Modern AI-based software systems are capable of automatically analyzing bone volume, mineral density, and the location of critical anatomical structures to determine the optimal implant position. These technologies enhance surgical safety, reduce operative time, and minimize the risk of complications. Additionally, the use of AI-supported surgical guides improves implant placement accuracy and predictability.

In orthodontics, the implementation of artificial intelligence has considerably simplified the diagnostic process. Automated cephalometric analysis, prediction of tooth movement, and simulation of aligner treatment effects reduce clinicians' workload and improve the precision of treatment planning. These advantages are particularly valuable in complex orthodontic cases where accurate clinical decision-making is essential.

Similarly, in prosthodontics, the integration of AI with digital modeling and CAD/CAM technologies enables the production of high-quality dental restorations with improved functional and aesthetic outcomes. AI algorithms can automatically evaluate occlusal relationships, distribution of masticatory forces, and anatomical characteristics. As a result, the accuracy of crowns, fixed dental prostheses, and other restorations is improved, while the need for clinical adjustments is reduced.

Despite these advantages, several challenges continue to limit the widespread implementation of artificial intelligence in dentistry. One of the major limitations is the dependence of algorithm performance on the quality and diversity of training datasets. If a neural network is trained using images obtained from a specific geographic region or a single healthcare

Received: 24.07.2026 / Accepted: 31.07.2026

institution, its diagnostic accuracy may decrease when applied to different populations. Therefore, the development of large-scale, multicenter international databases remains an important priority.

Another critical issue is the protection and security of medical information. AI systems require large volumes of medical images and patient-related clinical data for training and validation. Therefore, ensuring data privacy, cybersecurity, and compliance with international ethical standards represents one of the fundamental requirements of modern digital healthcare.

Ethical considerations also require careful attention. In cases where an AI system produces an incorrect diagnosis, the question of responsibility remains insufficiently defined. Current legal frameworks in many countries do not yet provide clear regulations regarding liability in such situations. Therefore, international organizations emphasize the need to establish unified legal and ethical standards for the safe and responsible use of artificial intelligence in healthcare.

In the Republic of Kazakhstan, the digital transformation of healthcare represents one of the important directions of national health policy. In recent years, digital health platforms, electronic medical records, and telemedicine systems have been actively implemented. These developments create favorable conditions for the introduction of AI technologies into dentistry. However, several barriers remain, including limited availability of national clinical databases, high costs of specialized software, and differences in digital competencies among healthcare professionals.

In the coming years, the development of artificial intelligence in dentistry will be closely associated with emerging technologies such as generative artificial intelligence (Generative AI), large language models (Large Language Models), explainable artificial intelligence (Explainable AI), federated learning, and digital twin technologies. These innovations have the potential not only to further improve diagnostic accuracy but also to enable prediction of individualized clinical scenarios, simulation of treatment outcomes, and development of fully personalized dental care approaches.

Overall, the findings of this review indicate that artificial intelligence is becoming an integral component of modern dentistry. Its effectiveness is demonstrated by improved diagnostic accuracy, accelerated clinical decision-making, and enhanced treatment outcomes. However, successful large-scale implementation requires further development of international standards, expansion of clinical research, protection of medical data security, and improvement of digital competencies among dental professionals.

Conclusion. The conducted literature review demonstrated that artificial intelligence technologies are being increasingly integrated into clinical practice in modern dentistry and significantly contribute to improving the efficiency of diagnostic and therapeutic processes. Machine learning and deep learning algorithms have shown high effectiveness in automated analysis of dental images, early detection of pathological changes, prediction of treatment outcomes, and support of clinical decision-making.

The analysis revealed that the highest performance of artificial intelligence has been observed in the diagnosis of dental caries, periapical pathologies, periodontal diseases, implant treatment planning, orthodontic assessment, and the design of prosthodontic restorations. In many clinical applications, the diagnostic accuracy of modern AI algorithms has reached levels comparable to those achieved by experienced dental professionals.

Received: 24.07.2026 / Accepted: 31.07.2026

Furthermore, artificial intelligence optimizes clinicians' workflow, reduces diagnostic errors, enables personalized treatment planning, and improves the overall quality of patient care. Particularly in the context of digital dentistry development, the integration of AI with cone-beam computed tomography (CBCT), digital radiography, CAD/CAM technologies, and intraoral scanning systems is creating new opportunities for advancing clinical practice.

Despite these advantages, the widespread implementation of artificial intelligence requires addressing several important challenges. These include the development of unified international standards, ensuring medical data security, improving algorithm reliability across diverse populations, strengthening legal and ethical regulations, and enhancing digital competencies among dental professionals.

In the Republic of Kazakhstan, the ongoing digital transformation of the healthcare system provides favorable conditions for the adoption of artificial intelligence technologies in dentistry. In the future, the development of national clinical databases, expansion of international scientific collaboration, and implementation of clinically validated intelligent systems may significantly improve the quality of dental care.

In conclusion, artificial intelligence should not be considered a replacement for dental professionals but rather an advanced clinical decision-support tool that enhances diagnostic accuracy and contributes to the improvement of evidence-based dental care. Further development of AI technologies will play an important role in establishing patient-centered, safe, and personalized approaches to dental treatment.

References

1. Khanagar SB, Al-Ehaideb A, Maganur PC, et al. *Developments, application, and performance of artificial intelligence in dentistry – A systematic review.* Journal of Dental Sciences. 2021; 16(1):508–522. DOI: 10.1016/j.jds.2020.06.019. https://pmc.ncbi.nlm.nih.gov/articles/PMC7770297/?utm_source=chatgpt.com

2. Mohammad-Rahimi H, Motamedian SR, Rohban MH, et al. *Deep learning for caries detection: A systematic review.* Journal of Dentistry. 2022;122:104115.

DOI:10.1016/j.jdent.2022.104115.

3. World Health Organization. *Ethics and governance of artificial intelligence for health: WHO guidance.* Geneva: WHO; 2021. ISBN 978-92-4-002920-0. WHO official publication

4. European Commission. *Ethics Guidelines for Trustworthy Artificial Intelligence.* Brussels; 2019. European Commission official page

5. Zhang X, Liang Y, Li W, et al. *Development and evaluation of deep learning for screening dental caries from oral photographs.* Oral Diseases. 2022;28(1):173–181. DOI: 10.1111/odi.13735.

6. Estai M, Tennant M, Gebauer D, et al. *Evaluation of a deep learning system for automatic detection of proximal surface dental caries on bitewing radiographs.* Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology. 2022;134(2):262–270. DOI: 10.1016/j.oooo.2022.03.008.

Received: 24.07.2026 / Accepted: 31.07.2026

7. García-Cañas Á, Bonfanti-Gris M, Paraíso-Medina S, et al. *Diagnosis of interproximal caries lesions in bitewing radiographs using a deep convolutional neural network-based software.* Caries Research. 2022;56(5–6):503–511. DOI: 10.1159/000527491.

8.Schwendicke F, Samek W, Krois J. *Artificial Intelligence in Dentistry: Chances and Challenges.* Journal of Dental Research. 2020;99(7):769–774. DOI: 10.1177/0022034520915714.

9. Cejudo JE, Chaurasia A, Feldberg B, Krois J, Schwendicke F. *Classification of Dental Radiographs Using Deep Learning.* Journal of Clinical Medicine. 2021;10(7):1496. DOI: 10.3390/jcm10071496.

10. Mörch CM, Atsu S, Cai W, et al. *Artificial Intelligence and Ethics in Dentistry: A Scoping Review.* Journal of Dental Research. 2021;100(13):1452–1460. DOI: 10.1177/00220345211013808.

11. Khanagar SB, Naik S, Al Kheraif AA, et al. *Application and Performance of Artificial Intelligence Technology in Oral Cancer Diagnosis and Prediction of Prognosis: A Systematic Review*. Diagnostics. 2021;11(6):1004. DOI: 10.3390/diagnostics11061004.

12. Ahmed N, Abbasi MS, Zuberi F, et al. Artificial Intelligence Techniques: Analysis, Application, and Outcome in Dentistry—A Systematic Review. BioMed Research International. 2021;2021:9751564. DOI: 10.1155/2021/9751564. https://pubmed.ncbi.nlm.nih.gov/34258283/

13. Karobari MI, Adil AH, Basheer SN, et al. *Evaluation of the Diagnostic and Prognostic Accuracy of Artificial Intelligence in Endodontic Dentistry: A Comprehensive Review of Literature.* 2023;2023:7049360. DOI: 10.1155/2023/7049360.

14. Dipalma G, Inchingolo AD, Inchingolo AM, et al. *Artificial Intelligence and Its Clinical Applications in Orthodontics: A Systematic Review.* Diagnostics. 2023;13(24):3677. DOI: 10.3390/diagnostics13243677.

15. Hartoonian S, Hosseini M, Yousefi I, et al. *Applications of artificial intelligence in dentomaxillofacial imaging: A systematic review*. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology. 2024;138(5):641–655. DOI: 10.1016/j.oooo.2023.12.790.

16. Parihar AS, Narang S, Tyagi S, et al. *Artificial Intelligence in Periodontics: A Comprehensive Review.* Journal of Pharmacy and Bioallied Sciences. 2024;16(Suppl 3):S1956–S1958. DOI: 10.4103/jpbs.jpbs_129_24.

17. Al Hendi KD, Alyami MH, Alkahtany M, et al. *Artificial intelligence in prosthodontics.* Bioinformation. 2024;20(3):238–242. DOI: 10.6026/973206300200238.

18. Ali IE, Tanikawa C, Chikai M, et al. *Applications and performance of artificial intelligence models in removable prosthodontics: A literature review.* Journal of Prosthodontic Research. 2024;68(3):358–367. DOI: 10.2186/jpr.JPR_D_23_00073.

19. Aljulayfi IS, Almatrafi AH, Althubaitiy RO, et al. *The potential of artificial intelligence in prosthodontics: A comprehensive review.* Medical Science Monitor. 2024;30:e944310. DOI: 10.12659/MSM.944310.

20. Bailey MA. *Ethical considerations for the integration of artificial and augmented intelligence in dentistry: Navigating the landscape and preparing for the future.* Journal of the American Dental Association. 2024;155(8):721–722. DOI: 10.1016/j.adaj.2024.05.010.

21. Rahim A, Khatoon R, Khan TA, et al. *Artificial intelligence-powered dentistry: Probing the potential, challenges, and ethicality of artificial intelligence in dentistry.* Digital Health. 2024;10. DOI: 10.1177/20552076241291345.

Received: 24.07.2026 / Accepted: 31.07.2026

22. Alfaraj A, Nagai T, AlQallaf H, Lin WS. *Race to the Moon or the Bottom? Applications, Performance, and Ethical Considerations of Artificial Intelligence in Prosthodontics and Implant Dentistry.* Dentistry Journal. 2025;13(1):13. DOI: 10.3390/dj13010013.

23. Tuygunov N, Samaranayake L, Khurshid Z, et al. *The Transformative Role of Artificial Intelligence in Dentistry: A Comprehensive Overview Part 2: The Promise and Perils, and the International Dental Federation Communique.* International Dental Journal. 2025;75(2):397–404. DOI: 10.1016/j.identj.2025.02.006.

24. Kaur N, Jacob G, Singh A, et al. *Artificial Intelligence in Dentistry: Balancing Innovation with Ethical Responsibility.* Bioinformation. 2025;21(3):489–494. DOI: 10.6026/973206300210489.

25. Di Cosola M, Ballini A, Prencipe FA, et al. *Artificial intelligence in dentistry: A narrative review of applications, challenges, and future directions.* Minerva Dental and Oral Sciences. 2025;74(5):337–348. DOI: 10.23736/S2724-6329.25.05217-9.

Received: 24.07.2026 / Accepted: 31.07.2026