Artificial Intelligence in Modern Dentistry: Diagnostic, Predictive, and Clinical Applications

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Abstract. *Artificial intelligence (AI) has become an integral component of contemporary dentistry, offering advanced solutions for diagnosis, treatment planning, patient education, and outcome prediction. Recent developments in machine learning and deep learning have enabled high-precision analysis of dental images, clinical data, and patient-specific factors. This review aims to critically evaluate current applications of AI in dentistry, focusing on diagnostic accuracy, orthodontic and restorative treatment planning, implantology, education, and predictive modeling. Relevant peer-reviewed studies were analyzed to assess the clinical effectiveness, limitations, and future prospects of AI-based systems.*

Keywords: *Artificial intelligence; Dentistry; Deep learning; Dental imaging; Clinical decision support; Orthodontic prediction; Digital dentistry*

Искусственный интеллект в современной стоматологии: диагностические, прогностические и клинические применения

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Аннотация. *Искусственный интеллект (ИИ) стал неотъемлемой частью современной стоматологии, предлагая передовые решения для диагностики, планирования лечения, обучения пациентов и прогнозирования результатов. Современные разработки в области машинного и глубокого обучения позволили достичь высокой точности анализа стоматологических изображений, клинических данных и индивидуальных особенностей пациентов. В данном обзоре проводится критическая оценка современных применений ИИ в стоматологии с акцентом на диагностическую точность, планирование ортодонтического и реставрационного лечения, имплантологию, образование и прогностическое моделирование. Были проанализированы*

соответствующие рецензируемые исследования для оценки клинический эффективности, ограничений и перспектив развития систем на основе ИИ.

Ключевые слова: *Искусственный интеллект; Стоматология; Дентальная визуализация; Клиническая поддержка решений; Ортодонтическое прогнозирование; Цифровая стоматология*

Zamonaviy stomatologiyada sun’iy intellekt: diagnostik, prognostik va klinik qo‘llanilishi

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Annotation. *Sun’iy intellekt (SI) zamonaviy stomatologiyaning ajralmas qismiga aylanib, diagnostika, davolashni rejalashtirish, bemorlarni o‘qitish va natijalarni bashorat qilish uchun ilg‘or yechimlarni taklif etmoqda. Mashinaviy va chuqur o‘rganish sohasidagi so‘nggi yutuqlar stomatologik tasvirlar, klinik ma’lumotlar hamda bemorlarga xos omillarni yuqori aniqlikda tahlil qilish imkonini berdi. Ushbu sharhda stomatologiyada sun’iy intellektdan foydalanishning hozirgi holati tanqidiy baholanib, diagnostik aniqlik, ortodontik va restavratsion davolashni rejalashtirish, implantologiya, ta’lim va bashoratli modellashtirishga alohida e’tibor qaratiladi. Tegishli ilmiy maqolalar tahlil qilinib, SI asosidagi tizimlarning klinik samaradorligi, cheklovlari va kelajakdagi rivojlanish istiqbollari baholandi.*

Kalit so’zlar: *Sun’iy intellekt; Stomatologiya; Dental tasvirlash; Klinik qarorlarni qo‘llab-quvvatlash; Ortodontik prognozlash; Raqamli stomatologiya*

1. Introduction

The rapid integration of artificial intelligence into healthcare has significantly transformed clinical decision-making and diagnostic processes. In dentistry, AI technologies are increasingly applied in radiographic interpretation, restorative planning, orthodontic prognosis, and patient management [1,2]. Deep learning models, particularly convolutional neural networks, enable automated feature extraction from dental images, improving diagnostic consistency and efficiency [3,4].

Despite promising results, concerns remain regarding data quality, ethical implications, and clinical validation [29,30]. Therefore, a comprehensive evaluation of AI applications in dentistry is essential to guide evidence-based implementation.

2. Artificial Intelligence in Dental Diagnostics

2.1 Radiographic Interpretation

AI-based systems have demonstrated high diagnostic accuracy in detecting dental caries, missing teeth, and supernumerary anomalies on panoramic and intraoral radiographs [3,4,25,26]. Szabó et al. reported that AI models achieved sensitivity comparable to experienced clinicians in caries detection [3]. Similarly, Makrygiannakis et al. validated AI software for identifying congenital tooth anomalies [4].

Systematic reviews confirm that deep learning improves diagnostic reliability while reducing observer variability [25]. However, performance is influenced by image quality and dataset diversity [26].

2.2 Forensic and Demographic Applications

In forensic dentistry, convolutional neural networks have been successfully used to estimate age and gender from dental records [7]. These tools enhance identification accuracy and reduce manual assessment time.

3. AI in Restorative Dentistry and Prosthodontics

AI has been widely adopted in restorative dentistry for caries classification, shade matching, and prosthetic planning [1,11–14,20]. Automated enamel caries detection models have demonstrated high classification accuracy in intraoral images [11].

Systematic reviews indicate that AI-assisted shade-matching systems improve color consistency in restorations [13]. Nevertheless, further clinical validation is required to ensure reproducibility [14].

Preliminary studies on prosthetic planning suggest that AI can optimize design workflows and material selection [20].

4. Orthodontics and Craniofacial Prediction

4.1 Treatment Outcome Prediction

AI-based predictive models are increasingly applied in orthodontics to estimate treatment outcomes and relapse risks [2,21,22]. Agrawal et al. developed a model incorporating retainer compliance and patient factors to predict relapse probability [2].

Comparative studies demonstrate that AI-based approaches outperform conventional regression methods in predicting treatment success [22,24].

4.2 Craniofacial and Soft Tissue Modeling

Advanced neural networks enable accurate prediction of craniofacial growth and postoperative soft tissue changes [23,24]. Kim et al. emphasized that dataset size significantly affects prediction accuracy [24].

Table 1. Summary of AI Applications in Dentistry

№	Authors	Article Type	Sample/Material	AI Type & Application	Evaluation Method	Result
1	Najeeb, Islam	Review	Literature	ML, DL – diagnostics	Systematic review	Improved accuracy
2	Agrawal et al.	Original	~300 patients	ML – relapse prediction	Statistical + AI	High accuracy
3	Szabó et al.	Validation	2500+ images	CNN – caries detection	ROC	Sensitivity >90%
4	Makrygiannakis et al.	Diagnostic	1800 panoramas	DL – anomaly detection	Accuracy	Reliable detection
5	Anny et al.	Epidemiological	2700 patients	Statistical + AI	Regression	Anomaly prevalence
6	Thorat et al.	Review	Literature	Chatbot, NLP	Narrative	Better education
7	Hundur Hiyari et al.	Experimental	1200 images	CNN – age/gender	Cross-validation	Accuracy >85%
8	Batgerel et al.	Cross-sectional	90 students	AI-assisted diagnosis	Comparison	Improved skills
9	Kurt, Şimsek	Comparative	200 cases	LLM models	Knowledge test	Strong knowledge
10	Durmazpinar, Ekmekci	Comparative	150 cases	ChatGPT-4o	Case analysis	Comparable results
11	Asiri	Diagnostic	3200 images	CNN – caries	DL testing	94% accuracy
12	Aziz et al.	Scoping review	Literature	Various AI	PRISMA	Wide adoption
13	Shetty et al.	Systematic review	Literature	DL – shade matching	Meta-analysis	Improved color
14	Alqutaibi	Critical review	Literature	ML – shade	Review	Needs validation

				analysis		
15	Alqutaibi, Aboalrejal	Review	Literature	AI – restorative	Review	Ongoing development
16	Alqutaibi	Review	Literature	AI – implant prediction	Review	Improved success
17	Proshchenko et al.	Original	400 implants	ANN – prediction	Model testing	Good prognosis
18	Elgarba et al.	Scoping review	Literature	AI planning	PRISMA	Reduced risk
19	Del Hougne et al.	In-silico	Virtual models	DL – prosthesis	Simulation	Faster planning
20	Kapoor et al.	Analytical	120 patients	ANN – decision support	Statistics	Better decisions
21	Cho et al.	Comparative	210 patients	ML – outcome	ROC	AI superior
22	Tanikawa, Yamashiro	Development	300 patients	DL – facial prediction	Validation	High conformity
23	Kim et al.	Modeling	500 children	DL – growth	Cross-validation	Stable results
24	Kim et al.	Methodological	Dataset	DL – soft tissue	Data analysis	Large data needed
25	Turosz et al.	Systematic review	Literature	Various DL	Meta-review	Effective radiology
26	Zhu et al.	Pilot study	1200 images	CNN – diagnosis	Accuracy	90%+ accuracy
27	Alhur	Review	Literature	LLM – support	Narrative	Clinical assistant
28	Grischke et al.	Review	Literature	Robotics + AI	Review	Digital progress
29	Pethani	Review	Literature	General AI	Critical review	Ethical risks
30	Nazemian et al.	Educational review	Literature	AI tools	Review	Training needed
31	Karnik et al.	Review	Literature	Robotics + AI	Review	Higher precision

5. Implantology and Surgical Planning

AI plays a critical role in implant planning and surgical simulation [17–19,31]. Scoping reviews highlight the effectiveness of AI in optimizing implant positioning and reducing surgical complications [18].

Predictive models also assist in estimating implant success rates and biomechanical stability [16,17]. Robotics-integrated systems further enhance surgical precision [31].

6. Artificial Intelligence in Dental Education and Communication

Recent studies reveal that AI tools improve diagnostic competence among dental students and support clinical training [8–10]. Batgerel et al. showed that AI assistance significantly enhanced caries detection performance among senior students [8].

Large language models such as ChatGPT and Gemini demonstrate potential in clinical reasoning and patient education [6,9,27]. However, limitations related to accuracy and contextual understanding remain [9,27].

7. Ethical, Technical, and Clinical Challenges

Although AI systems offer substantial benefits, several challenges hinder their widespread adoption. These include data privacy, algorithmic bias, lack of transparency, and regulatory uncertainty [29,30].

Inconsistent reporting standards and limited external validation further restrict clinical generalizability [1,15]. Therefore, multidisciplinary collaboration is required to establish robust guidelines.

8. Future Perspectives

Future research should focus on multi-center datasets, explainable AI models, and real-time clinical integration. Combining AI with robotics and digital workflows may further enhance personalized dentistry [28,31].

Longitudinal studies are needed to assess long-term clinical outcomes and cost-effectiveness [15,21].

9. Conclusion

Artificial intelligence has transformed modern dentistry by enhancing diagnostic accuracy, treatment planning, and educational strategies. Current evidence supports its clinical potential in radiology, orthodontics, restorative dentistry, and implantology. However, ethical, technical, and regulatory challenges must be

addressed to ensure safe and effective implementation. Continued interdisciplinary research will be essential for integrating AI into routine dental practice.

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