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Impediments to AI Integration in Dentistry: A Review

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Abstract: Artificial intelligence (AI) is undoubtedly the technology of the decade. Although AI offers considerable potential for diagnosis, treatment planning, and workflow optimization, its adoption is limited by data privacy concerns, absence of standardized datasets, AI black box, high costs, and inadequate training and skepticism among clinicians. Thirty five articles were short listed following google scholar search with the key words (AI, AI limitations, AI Ethics, AI roadblocks in dentistry, LLMs, Generative AI in dentistry, AI in future dentistry) out of which 12 articles were excluded for not meeting the criteria. As dentists, learning the fundamentals of AI and understanding the barriers to AI implementation is necessary for the smooth and efficient integration of the technology. This article is an attempt to shed light on some of the impediments to AI integration in dentistry.

Keywords: AI, Black Box AI, AI in Dentistry, Barriers to AI in dentistry, AI Ethics.

Review Article

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INTRODUCTION

Extensive research into the development of machines capable of performing human-like tasks began as early as the mid-20th century. John McCarthy introduced the term " artificial intelligence" in 1955[1]. Artificial intelligence (AI) is founded on key principles, including machine learning, deep learning, and representation learning. Machine learning is a fundamental component of AI in which algorithms learn intrinsic statistical patterns and structures within data, enabling predictions on previously unseen data. A significant type of machine learning model is the neural network, which often outperforms traditional algorithms, particularly when applied to complex data such as images or radiographs [1, 2].

Deep learning is a subcategory of machine learning that encompasses a broader set of methods based on artificial neural networks. These methods are applied in drug manufacturing, radiological image interpretation, and histopathological condition identification, all of which have demonstrated comparable findings.

This model enables the machine to make judgments without explicit programming to complete specific tasks. Representation Learning: This method does not require manual categorization of data. Instead, the machine learning system identifies the characteristic required for categorization. The biological neural system, characterized by a large number of interconnected neurons involved in learning is mimicked by artificial neural networks (ANNs), which use algorithms to comprehend the relationship between attributes and the ground truth [3]. Healthcare is a sensitive and highly regulated field in which every action requires validation and evidence.

The human-centered nature of healthcare contributes to its nobility. Although AI can significantly improve the standard of care in dentistry, offering confidence among clinicians and patients remains a challenge. The scope of AI in dentistry encompasses all aspects of the field, ranging from patient management and workflow to diagnosis, treatment planning, and prognosis. This article aims to highlight some of the obstacles to implementing AI in daily dental practice [Figure 1].

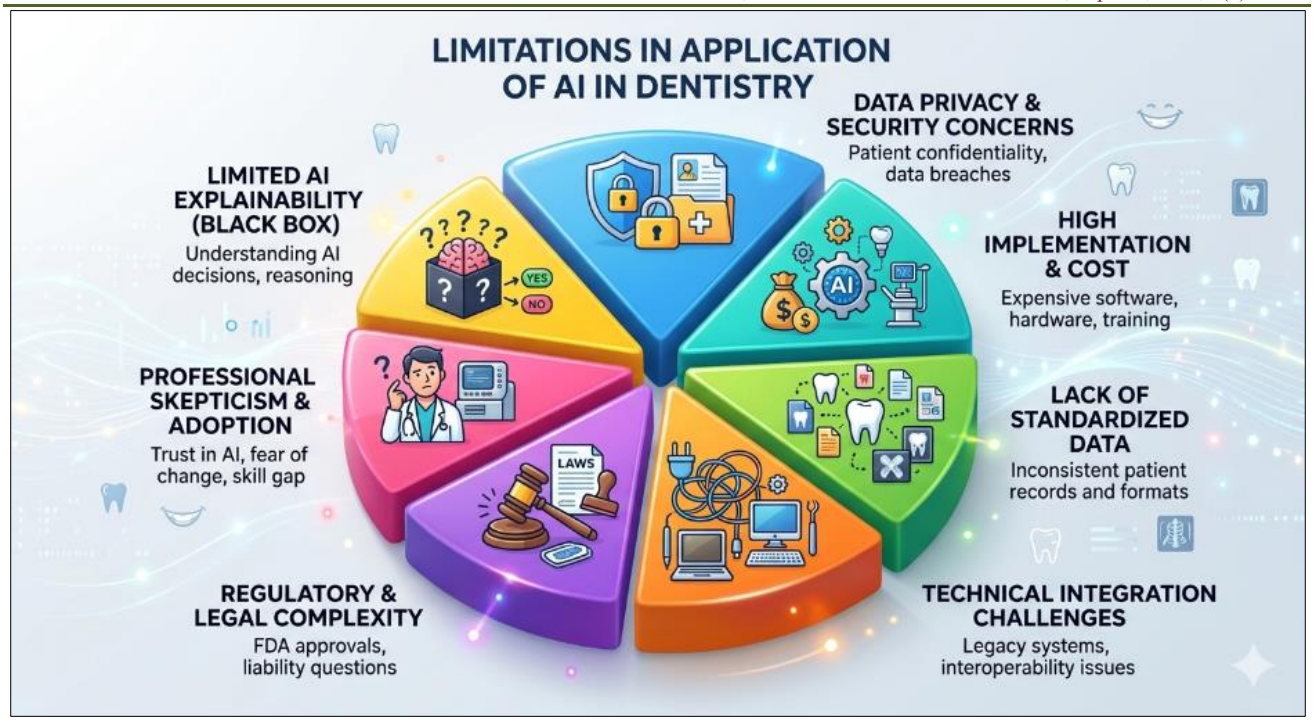

Figure 1: Challenges to AI integration in dentistry. (Image created by author using *nano banana)*

Despite its significant potential, AI has not yet been integrated into routine dental practice. Convolutional neural networks (CNNs) have only been adopted in dental research over the past decade. Medical and dental data are primarily less accessible than other types of data. These data are not as readily available or accessible as data in other fields [1, 2]. Due to data protection concerns and organizational barriers, dental data is further limited in availability and accessibility. Dental data are frequently stored within individualized systems that lack interoperability. Many systems lack interoperability, and available datasets are often unstructured and limited in size [3].

Application Readiness and Skepticism

The outcomes of AI applications in dentistry are often not directly applicable, as most systems provide information that only partially supports the complex decision-making required in clinical care [4]. This limitation affects the quality of clinical decision-making. Furthermore, unresolved questions persist regarding responsibility and transparency in AI-assisted dental care. Regulatory frameworks for AI use in medical practice remain underdeveloped, resulting in ongoing uncertainty about compliance and accountability. Technological and financial barriers also hinder adoption [5, 6]. For example, a study in Jordan found that 42% of participants agreed or strongly agreed with the use of AI-powered tools during dental procedures, 40.2% remained neutral, and 17.7% disagreed or strongly disagreed [7]. Another study reported that approximately 45% of respondents supported the use of specialised AI software for data collection and analysis but emphasized that a qualified dentist should make the final diagnosis. Trust in diagnoses made entirely by AI remained statistically low across all groups: 3.8% among dentists, 10.4% among dental students, and 10.8% among other respondents. These findings align with those of Stai *et al*., who observed similar levels of trust in AI-generated and clinician-made diagnoses. Notably, more than half of respondents (55%) reported discomfort with automated robotic surgery [8]. The majority of dentists preferred to rely on their own clinical judgment rather than AI for diagnostic purposes [9]. However, over 50% of dentists preferred an AI-assisted diagnostic workflow over relying solely on AI [10].

High Costs and Insufficient Training

Barriers to AI integration include high costs for AI-powered diagnostics and inadequate interoperability. Inadequate training in AI use contributes to dental professionals' hesitation and limited integration of AI [11]. The high costs of AI diagnostics and poor interoperability with existing dental software further complicated integration. Collaboration among regulators, researchers, and dental practitioners is necessary to address these barriers. AI decision-making should be designed to complement, rather than replace expertise of professionals, allowing clinicians to exercise critical thinking and maintain independence when working with patients. Clinicians should retain latitude for critical thinking and independence when working with patients [12].

Ethical and Legal Considerations

The legal dimensions of AI in dentistry extend to accountability and liability. Employing technology in current legislation does not address this issue. AI-dependent medical decision-making necessitates the development of new legal frameworks to establish accountability. An ethical dilemma arises when AI is not employed for cost-saving purposes, particularly if this compromises patient care [12, 13]. Besides, the ethical use of AI in dental education and training must also be considered. AI implementation must adhere to ethical principles such as transparency, patient autonomy, and fairness to maintain professional integrity and patient trust. Ethical use of AI should preserve both professional integrity and patient trust. A growing discussion among stakeholders, including policymakers, dentists, and AI engineers, is necessary [11].

Regulatory Compliance

Compliance with FDA criteria renders AI-assisted dental technologies subject to stringent safety, efficacy, and ethical standards, significantly impacting their acceptance and application in clinical practice. Practitioners lack awareness, and a lack of awareness and familiarity with AI tools among practitioners leads to skepticism and reluctance to utilize AI-powered diagnostic tools [11]. In a survey conducted in Croatia, 71% of dentists agreed that AI is usable, but 76% have not utilized AI tools in practice, citing high lack of awareness. Limited awareness of AI's applicability remains a barrier to adoption. Trust and liability concern also cause hesitation among dentists regarding AI use, and practitioners express concern about the accuracy of AI-assisted diagnoses as AI-generated predictions may sometimes conflict with clinicians' expertise. No consensus exists regarding accountability for incorrect diagnoses facilitated by AI [11-15]. Artificial intelligence algorithms are trained on large datasets; however, insufficient diversity in these datasets can amplify biases and result in inequalities in dental planning and diagnosis. Such biases may yield inequalities in dental planning and diagnoses. AI frameworks should prioritise diversity, equity, and inclusion to ensure fair and accurate outcomes for diverse patient populations. fair and correct information for a range of patient groups[16]. The recently proposed European Union AI Act represents a significant international effort to regulate AI systems through legal frameworks, establishing risk categories and corresponding mandates for transparency, robustness, and data protection. This initiative emphasises ethical accountability and risk management to ensure the ethical application of AI in healthcare and dentistry. Similarly, the United States Food and Drug Administration (FDA) is exemplary and offers explicit rules, including the Software as a Medical Device (SaMD) regulation [17].

Black Box AI

The lack of explainability in many AI models, often referred to as 'black-box AI', raises significant concerns. Limited explainability, sometimes termed 'black box medicine', poses challenges to the adoption of AI in healthcare. AI is gaining considerable traction these days, including text-related, image-related, or combined applications. related, image-related, or a combination of both. Applications for the public, such as Chat-GPT, Midjourney, and other AI image enhancers, have seen rapid adoption [17, 18]. Besides general-purpose applications, machine learning engineers have been addressing challenges in medical imaging with these innovative techniques. In this regard, a popular focus is on improving image quality and resolution [19]. Various algorithmic attempts have been employed to approximate adjustments to eliminate unintentional image distortions. The mathematical foundations of these approaches require critical evaluation. Although post-processed images may appear clearer, their use in diagnostic contexts remains contentious. Their adoption for diagnostic purposes can be contentious. Post-processing algorithmic approaches, such as metal artefact reduction (MAR) and Image upscaling, enhance visual image quality by eliminating noise and artefacts and improving detail. End images can appear natural and more defined for visualisation, while actually containing inaccuracies, distortion, and irretrievable information loss due to the estimation process. Consequently, post-processed images are generally not ideal for diagnostic purposes. Concerns exist about anatomical authenticity in algorithm-modified regions. Estimation algorithms [Figure 2]. For instance, several studies have suggested an adverse effect of MAR algorithms when detecting root fractures in cone-beam CT images in endodontically-treated teeth or around metal posts [18-21]. One suggested mitigation is the careful evaluation of the original and processed images during examinations.

AI "Hallucinations"

A major concern with large language models is the ability to generate false diagnoses, which could be based on poor training data. The interesting aspect is that the system comes up with such false results which may look completely plausible. Processing deficient data in this manner results in what is termed an AI hallucination [22, 23].

Another concern with LLM and LMM approaches is their tendency to be confident while also being incorrect. It is unacceptable for a system to generate false diagnoses based on poor training or,

worse, to produce post hoc reasoning that is false or misleading about a diagnosis or treatment. The slang term for this phenomenon is "hallucinating," where the model generates words that sound plausible but are not true.

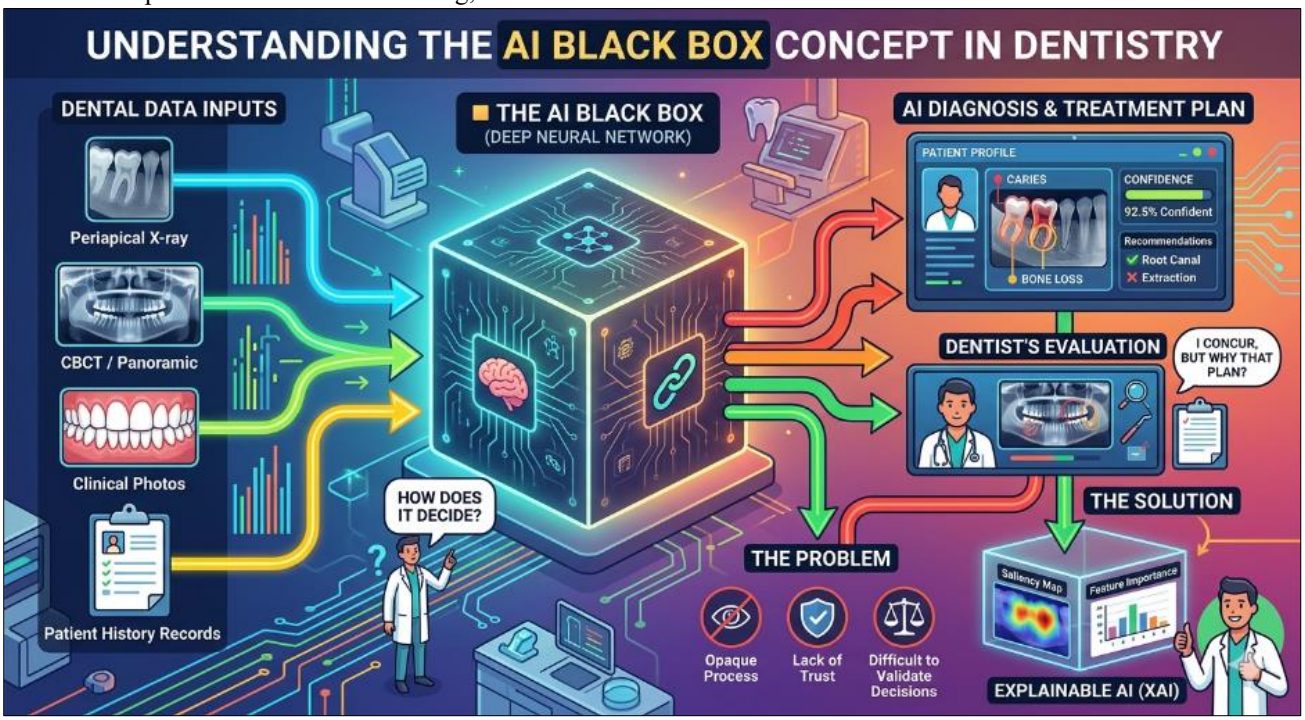

Figure 2: AI black box concept. (Image created by author using *nano banana)*

Explainable Artificial Intelligence (XAI) Explainable AI (XAI) is a novel approach designed to enhance transparency in AI systems. Current AI decision-making can be explained in terms of logic, making the system accountable and regulatable. XAI has emerged as an essential realm aimed at tackling the opacity of intricate AI models and nurturing confidence in their judgments. This study provides an extensive investigation of the fundamental principles, methodologies, and practical implementations of XAI. The foundation of XAI is the urgent need to demystify the internal mechanisms of AI models, making their decision-making processes transparent to human stakeholders [22].

Conclusion

Modern dental practice depends on advanced technologies such as electronic patient records, radiography, 3D photography, and intra-oral scanners. While integrating AI into these systems poses significant challenges, both dentists and patients have shown generally positive attitudes toward its adoption. However, there is still a substantial gap concerning ethical and privacy issues that must be resolved before widespread implementation. Relevant authorities should address these concerns at a global level [9-17].

AI requires large datasets, making platforms like OpenAI particularly promising. Explainable AI can transform dental diagnosis and treatment planning by providing logical and transparent results. Incorporating AI into dentistry is essential to enhance patient comfort and clinical workflow, while maintaining the human aspect of care.

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