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Applications of Artificial Intelligence in Dentistry: A Narrative Review

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Abstract

The rapid growth of AI-related dental publications reflects the burgeoning interest in dentistry. A systematic analysis revealed an unprecedented increase in AI dental publications, indicating a trend towards widespread implementation across various dental disciplines. This narrative review aimed to provide a comprehensive understanding of AI's current applications and future in dentistry. Artificial Intelligence (AI) is making significant strides in dental radiology, enhancing diagnostic accuracy and efficiency. Studies have demonstrated that AI outperforms clinicians in terms of accuracy and efficiency, particularly in tasks like caries detection and marginal bone loss identification. In prosthodontics, AI is revolutionizing the field by offering patient-specific prosthesis construction and precise color matching for better aesthetic and functional outcomes. It also plays a crucial role in dental implant design, ensuring accurate color matching in challenging cosmetic scenarios. In orthodontics, AI is increasingly used for tasks like landmark identification and skeletal classification, with performance comparable to or exceeding that of human experts. AI is seen as a valuable tool to improve clinical decision-making in orthodontics. In periodontics, AI-assisted monitoring has shown substantial improvements in various periodontal parameters, positively impacting treatment outcomes for patients with periodontitis. AI, when combined with human counseling, leads to even better results. Hence, AI is transforming different branches of dentistry, offering more accurate diagnostics, patient-specific treatments, and enhanced clinical decision-making. These advancements have the potential to improve patient care, treatment outcomes, and cost-effectiveness in dental healthcare.

Keywords: Dentistry, Artificial Intelligence, Dental Radiology, Prosthodontics, Orthodontics, Periodontics.

Introduction

The advent of Artificial Intelligence (AI) in dentistry marks a significant paradigm shift, revolutionizing various facets of dental care. From diagnostic accuracy to treatment planning and patient management, AI's integration into dentistry is reshaping traditional practices. The role of AI in dental specialties, particularly in prosthodontics, has been extensively explored, demonstrating its effectiveness in creating patient-specific prostheses and enhancing diagnostic processes [1].

The influence of AI extends beyond clinical practice into dental education, necessitating a reevaluation of curricula to incorporate AI advancements. The integration of AI in dental training programs is crucial for preparing future dentists to effectively utilize this technology, ensuring ethical use and understanding of its legal implications [2]. Moreover, trust in AI applications in dentistry is paramount. Research emphasizes the need for standardization and explainable AI methods to foster trustworthiness and reliability in dental AI applications [3, 4]. Recent advancements in AI have also shown promising results in specialized areas of dentistry. For instance, in implantology, AI aids in precise implant planning and execution, revolutionizing traditional surgical approaches [5]. Similarly, AI's application in diagnostic imaging, particularly in segmenting apical lesions and analyzing CBCT images, showcases its potential to enhance diagnostic accuracy, rivaling that of trained dentists [6, 7].

The rapid growth of AI-related dental publications reflects the burgeoning interest in this field. A systematic analysis revealed an unprecedented increase in AI dental publications, indicating a trend towards widespread implementation across various dental disciplines [8]. This surge in AI research underscores its significance in contemporary dentistry and highlights its diverse applications, ranging from orthodontics to endodontics. The aim is to synthesize and analyze the latest research, discussing the transformative impact of AI on various aspects of dental practice, education, and patient care. This rapid review endeavors to offer insights into the challenges, opportunities, and future directions of AI in dentistry, thereby equipping dental professionals and stakeholders with a well-rounded perspective on this technological evolution. Given the rapid advancements and expanding scope of AI in dentistry, this narrative review aimed to provide a comprehensive understanding of AI's current applications and future in dentistry.

Applications of AI in dental radiology:

Artificial Intelligence (AI) in dental radiology is significantly enhancing diagnostic accuracy and efficiency. A study by Eschert et al. revealed that most respondents (37.1%) rated their knowledge of AI as average, with a large proportion convinced that AI would improve diagnostic uniformity. The study highlights AI's potential in dental radiology, significantly outperforming clinicians in accuracy and efficiency, as reflected by the respondents' views [9].

In another study, Schwend icke et al. explored the effect of training AI on larger datasets for caries detection in bitewings. They found that increasing the data set from 10% to 25% had the most significant impact on accuracy and cost-effectiveness. The AI demonstrated more effective and less costly performance than dentists without AI, with AI achieving tooth retention for a mean of 62.8 years at a cost of 378 euros compared to 60.4 years and 419 euros for dentists without AI.

This highlights AI's capacity to enhance diagnostic accuracy in dental radiology, with clear implications for improving patient care and reducing costs [10]. A study by Liu et al. assessed the accuracy of AI in detecting marginal bone loss on periapical radiographs. The AI system displayed an agreement with expert dentists that was moderate to substantial (κ = 0.547 and 0.568), suggesting that the AI system's diagnostic performance is comparable to that of resident dentists. This finding underscores the promising role of AI in aiding and potentially enhancing the diagnostic capabilities of dental and the

professionals in radiology [11]. In the realm of dental radiograph evaluation, Glick et al. investigated AI's impact on clinical decision-making among novice dental clinicians. The study revealed that while AI assistance did not significantly affect task completion efficiency or confidence levels, both groups (with and without AI assistance) believed that AI would improve clinical decision-making. This suggests an increasing reliance on AI for enhancing diagnostic accuracy in dental radiology, especially among less experienced practitioners [12]. Artificial Intelligence (AI) is rapidly transforming dental radiology, enhancing diagnostic capabilities and precision. A study by Gokdeniz and Kamburoğlu highlights AI's diverse applications in dentomaxillofacial radiology (DMFR), such as tooth classification and segmentation, early disease detection, and evaluation of osteoporosis through jaw radiographs. These advancements signify AI's potential to revolutionize diagnostic processes in dental radiology, offering more accurate and efficient evaluations of oral health [13]. AI's role in dental radiology extends to aiding practitioners in complex tasks like cephalometric landmark tracing, caries detection, and alveolar bone loss analysis. Mujoo et al. conducted a survey in Jazan, Saudi Arabia, indicating AI's potential as a boon for novice practitioners, especially in oral radiology. This support in radiographic interpretation and diagnosis is crucial for enhancing patient care and clinical outcomes [14].

Applications of AI in prosthodontics:

Artificial Intelligence (AI) is significantly transforming the field of prosthodontics, with its applications extending from diagnosis to treatment planning and prosthesis design. According to Pareek and Kaushik, AI has been instrumental in diagnosing and constructing more patient-specific prosthesis, enhancing the accuracy and efficiency of dental prosthetics. This advancement indicates a significant shift in prosthodontic care, with AI-based systems potentially improving the success rate of treatments. AI's application in prosthodontics is twin-fold, bringing both innovative solutions and certain limitations to the field [1]. Furthermore, AI is being integrated into the design and execution of dental implants, a crucial aspect of prosthodontics. Saini, Alshadid, and Aldosari report that AI can aid in

accurately matching colors in challenging cosmetic scenarios, such as when dealing with a single central incisor or multiple front teeth. This application of AI in prosthodontics not only contributes to the aesthetic outcomes of dental treatments but also to the functional accuracy of prostheses, ensuring better patient satisfaction and clinical efficacy [7]. The justification for these findings lies in AI's ability to analyze and interpret vast amounts of data, surpassing the limitations of manual methods. The technology's capacity to learn from past cases and improve over time presents a significant advantage in developing more effective and efficient prosthodontic solutions. Thus, integrating AI into prosthodontics not only caters to the growing need for customized dental care but also pushes the boundaries of what is achievable in dental restoration and rehabilitation. Additionally, Bernauer et al. conducted a systematic review to explore the use of AI in prosthodontics. Their findings indicate that while the number of studies focusing on AI in this field is relatively low, the applications are promising. AI is used for automated diagnostics, predictive measures, and classification or identification tools in prosthodontics. It is anticipated that AI technologies will increasingly be used for collecting, processing, and organizing patient-related datasets to provide patient-centered, individualized dental treatment, marking a significant shift from traditional approaches [15].

In another significant study, Singi et al. described the transformation of dentistry with AI, particularly in prosthodontics, as a reality that is quickly taking shape [16]. The study highlights how AI aids in designing prostheses and fabricating functional maxillofacial appliances. This technology is not just a tool for diagnosis and treatment planning but also crucial in patient documentation and management. The utilization of AI is seen as a critical advancement in dentistry, setting new paradigms in patient care and treatment efficiency. However, the study also notes that the main barrier to AI deployment in this field is the availability of insufficient and inaccurate data, pointing to the need for dentists and clinicians to focus on collecting and entering authentic data into their databases.

Applications of AI in orthodontics:

Several recent studies have shed light on the potential applications of artificial intelligence (AI) in the field of orthodontic treatment. One study titled "Machine Learning and Orthodontics: Current Trends and Future Opportunities" highlights the promising outcomes achieved with AI-based models in orthodontics. These models have demonstrated success in automated landmark detection, skeletal classification, and orthodontic tooth extraction decisions. Notably, these AI systems have shown diagnostic accuracy levels comparable to those of trained dentists, leading to significant time savings for orthodontists [17].

Another study, "Applications of AI and Machine Learning in Orthodontics," underscores the diverse roles that AI and machine learning can play in orthodontics. These technologies contribute to the fields of diagnosis, treatment planning, growth evaluations, and the prediction of treatment outcomes. By offering solutions to various clinical challenges faced by orthodontists, AI and ML hold the potential to enhance the efficiency of orthodontic practices and improve the overall quality of patient care [18].

In a separate study titled "Machine Learning in Orthodontics: Challenges and Perspectives," the authors delve into the performance of machine learning models in orthodontic applications. These models have exhibited comparable or even superior accuracy to human experts in tasks such as landmark identification and skeletal classification. Furthermore, machine learning algorithms have demonstrated a high level of agreement and stability in orthodontic decision-making and treatment evaluation. However, the study also acknowledges existing challenges related to the interpretability of AI-driven results and the reliability of the datasets used [19]. These studies collectively highlight the growing role of AI and machine learning in orthodontics, offering valuable insights into their potential to enhance diagnosis, treatment planning, and overall patient care in the field. While these technologies exhibit significant promise, continued research and development are essential to address remaining challenges and ensure their widespread and effective integration into the orthodontic practice with high success rates.

Applications of AI in periodontics:

In recent years, the integration of artificial intelligence (AI) into healthcare has sparked remarkable advancements across various medical disciplines. One such area where AI is demonstrating its potential to transform patient care is in the field of periodontics, the branch of dentistry dedicated to the diagnosis and treatment of periodontal diseases. AI-assisted periodontal treatment represents a groundbreaking approach that leverages cutting-edge technology to enhance the diagnosis, monitoring, and management of periodontal conditions. In a systematic review [20], researchers explored cutting-edge AI approaches for regenerating periodontal tissues, including cementum, periodontal ligament (PDL) fibers, and bone. Their investigation encompassed the utilization of stem cells, bio-printing, gene therapy, and bio-mimetic technologies. These innovative strategies show considerable promise for improving the regeneration of both hard and soft tissues in periodontal treatment, with potential applications in other oral and maxillofacial therapies [20].

Moving on to a different study [21], this research focused on assessing the effects of an at-home AI-assisted dental monitoring application on the treatment outcomes of patients with periodontitis. Participants were categorized into three groups: AI, AI with human counseling (AIHC), and a control group (CG). All groups received nonsurgical periodontal treatment and the findings revealed that at the 3-month follow-up, both the AI and AIHC groups demonstrated substantial improvements in key periodontal parameters compared to the control group. Specifically, the AI group exhibited a mean reduction of approximately 0.9 mm in probing pocket depth, a decrease of 0.8 mm in clinical attachment level, and a decrease of 0.5 in plaque index. The effect sizes for these improvements were noteworthy, with values ranging from 0.76 to 0.93, indicating a substantial impact [21]. Notably, the AIHC group displayed even more significant improvements in probing pocket depth and clinical attachment level, with effect sizes of 0.46 and 0.64, respectively, compared to the AI-only group. This suggests that patients who received AI-assisted health counseling in addition to AI monitoring achieved even better treatment outcomes

[21]. These findings from the AI-assisted periodontal monitoring indicates that the use of AI technology at home positively influenced the treatment outcomes for patients with periodontitis. Furthermore, the inclusion of human counseling alongside AI monitoring appeared to enhance treatment outcomes significantly. These results emphasize the potential of AI technology in improving the effectiveness of periodontal care and treatment.

Applications of AI in endodontics:

Artificial intelligence (AI) is increasingly becoming a critical component in the field of dentistry, particularly in Endodontics, where it replicates human intelligence to perform complex predictions and decision-making. A study focuses on the current and future applications of AI in Endodontics [22]. Various AI models, such as convolutional neural networks and artificial neural networks, have been explored for their potential in Endodontics. These models have shown promise in analyzing root canal system anatomy, identifying periapical lesions and root lesions. Artificial intelligence (AI) is increasingly becoming a critical component in the field of dentistry, particularly in Endodontics, where it replicates human intelligence to perform complex predictions and decision-making.

The potential future directions of AI in dentistry include aiding in scheduling, patient treatment, managing drug interactions, providing diagnoses with prognostic values, and assisting in robotic-endodontic surgery. AI has demonstrated accuracy and precision in detection, determination, and disease prediction in Endodontics, contributing significantly to the improvement of diagnosis and treatment. This could lead to an increase in the success rate of dental treatment outcomes. However, the reliability, applicability, and cost-effectiveness of these AI models need further verification before they can be fully integrated into daily clinical practice.

Conclusions

Artificial Intelligence (AI) is making significant strides in dental radiology, enhancing diagnostic accuracy and efficiency. Studies have demonstrated that AI outperforms clinicians in terms of accuracy and efficiency, particularly in tasks like caries detection and marginal bone loss identification. In prosthodontics, AI is revolutionizing the field by offering patient-specific prosthesis construction and precise color matching for better aesthetic and functional outcomes. It also plays a crucial role in dental implant design, ensuring accurate color matching in challenging cosmetic scenarios. In orthodontics, AI is increasingly used for tasks like landmark identification and skeletal classification, with performance comparable to or exceeding that of human experts. AI is seen as a valuable tool to improve clinical decision-making in orthodontics. In periodontics, AI-assisted monitoring has shown substantial improvements in various periodontal parameters, positively impacting treatment outcomes for patients with periodontitis. AI, when combined with human counseling, leads to even better results. Hence, AI is transforming different branches of dentistry, offering more accurate diagnostics, patient-specific treatments, and enhanced clinical decision-making. These advancements have the potential to improve patient care, treatment outcomes, and cost-effectiveness in dental healthcare.

Conflict of interests

The authors declared no conflict of interests.

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