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Enhancing dental medication management through artificial intelligence: A comprehensive review of contributions from nursing, dentistry, and pharmacy

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***Abstract*---Background**: The integration of Artificial Intelligence (AI) in healthcare, particularly in dental medication management, has the potential to enhance treatment efficacy and patient outcomes. The rising prevalence of dental diseases, coupled with a shortage of professionals, necessitates innovative solutions to improve care delivery. **Methods**: This review analyzes AI applications in dentistry, focusing on literature published from 2000 to 2021. Key databases, including PubMed and Web of Science, were utilized to gather studies employing AI models, particularly convolutional neural networks (CNNs), for diagnosing dental conditions and managing medication. **Results**: The findings indicate a significant increase in AI research within dentistry, highlighting its effectiveness in diagnostic accuracy and efficiency. AI models demonstrated high precision in identifying dental caries, periodontal diseases, and other oral health issues. Notable advancements include automated systems for radiographic analysis and clinical decision support, which have streamlined workflows and reduced the burden on dental professionals.

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Conclusion: AI holds transformative potential in dental medication management by facilitating accurate diagnoses and personalized treatment plans. While current applications show promise, further research is required to assess the cost-effectiveness and long-term implications of AI integration in clinical practice. The future of dental care may increasingly rely on AI-driven technologies to enhance patient outcomes and address workforce challenges.

***Keywords*---**Artificial Intelligence, dental medication management, convolutional neural networks, diagnostic accuracy, healthcare innovation.

1. Introduction

Since the inception of scientific inquiry, scientists and engineers have endeavored to elucidate the complexities of the human brain, an intricate network of billions of neurons transmitting information throughout the body [1,2]. The human brain may be seen as a sophisticated network of linked neurons that interact by delivering electrical impulses throughout the body. The scientific community persists in encountering difficulties in creating a model that precisely emulates the intricacies of the human brain. For numerous years, dedicated researchers have been actively involved in the development of a notion termed “Artificial Intelligence” [3]. The term "Artificial Intelligence" (AI) originated in the 1950s and refers to the development of machines capable of emulating human intellect and behavior [4].

In 2015, the direct and indirect costs associated with the treatment of oral and dental illnesses, prevalent health issues globally, exceeded USD 500 billion [5]. The prevalence of oral and dental disorders is anticipated to rise owing to demographic and epidemiological changes; yet there exists a limited number of professionals equipped to provide oral and dental treatment. This is imposing more pressure on already strained healthcare systems, jeopardizing the accessibility and cost of oral and dental health treatments.

AI and its applications have been seen as both advantageous and detrimental throughout the last seventy years. Throughout this period, several instances have occurred when technology developments have not met expectations. The last decade signifies the pinnacle of artificial intelligence. The present state-of-the-art artificial intelligence-driven natural language modeling has grown so persuasive that readers are unable to distinguish between material authored by humans and that produced by machines. The second advancement is facing recognition technologies. The influence of AI-driven technology on several aspects of society, such as healthcare and politics, has reached a critical juncture. One of these disciplines is dentistry [6,7]. The potential of AI to enhance efficacy, safety, and efficiency in oral and dental care is especially intriguing since it will provide the delivery of superior treatment to a larger population in a reduced timeframe.

This article reports on the use and performance of AI models created for use in dentistry. Notable online databases, such as PubMed and Web of Science, were used to obtain papers relevant to the study question published from 2000 to 2021. The bulk of the trials included in the investigation used convolutional neural networks. In the last five years, there has been a significant increase in the number of academic publications reporting the use of artificial intelligence (AI) models.

2. Artificial Intelligence

Artificial intelligence (AI) is described as the ability of machines to exhibit a unique kind of intellect. This work aimed to build and create robots capable of extracting information from data to successfully solve diverse challenges [10]. Current research and performance measures for assessing machine learning (ML) models have not shown an improvement in clinical outcomes. Although models can accurately diagnose disorders in images or formulate hypotheses from electronic health records, it is the clinician's recommendations for therapy that ultimately influence clinical outcomes by considering the patient holistically, the overall advantages of available treatment options, and the patient's readiness to adhere to treatment.

Although a model may excel in predicting periodontal disease, the efficacy of the clinical result is significantly contingent upon the practitioner’s capacity to modify a patient’s smoking habit [11,12]. Consequently, it is recommended that an evaluative framework be developed that considers events following the outputs of the ML model to provide a comprehensive understanding of the model's influence on patient outcomes. To adapt to local changes and guarantee maximum performance and patient safety, ML systems require constant monitoring, retraining, and maintenance [13].

Data-driven machine learning models are often lauded as impartial decision-making systems free from human biases. However, the unintentional incorporation of human biases into these systems may happen, presenting a specific issue with black box algorithms, where recognizing and rectifying such biases may be especially difficult. There is an increasing acknowledgment of the capacity of ML models to sustain or exacerbate existing societal biases and health disparities. The ability to improve patient care and provide precise diagnoses has transformed the healthcare sector. The capacity to instruct patients on behavioral modification while doing dental operations is highly sought after. This is particularly applicable in pediatric dentistry [14,15].

3. Utilizations in Dentistry

Artificial intelligence is crucial in modernizing traditional techniques in dentistry. Artificial intelligence technologies are often used in the creation of automated software systems that improve the efficiency of diagnostics and data management in dentistry. Clinical decision support systems primarily function as instruments that assist and guide professionals in enhancing decision-making. These strategies have been used to improve diagnostic accuracy, assist in treatment plan creation, and provide prognostic predictions. The rising demand for these systems is due to their effectiveness in providing explanations and logical reasoning [15]

Numerous AI-driven solutions are now used to optimize and automate formerly laborious dental processes. These technologies provide several beneficial services, such as improved diagnostic precision, illness forecasting, and treatment suggestions, to alleviate the dentist's labor. Artificial intelligence is used in several domains of dentistry, ranging from cavity detection to gender identification in forensic dentistry [16].

The use of AI has revolutionized the dentistry industry and streamlined the tasks of dentists. The primary role of AI-driven clinical decision support systems is to aid physicians and nurses. A clinical decision support system refers to any computer software that processes medical data or the requisite medical expertise for interpreting such data, aimed at assisting healthcare professionals in clinical decision-making [17].

The use and influence of artificial intelligence (AI) have significantly increased across several sectors, including dentistry. The capacity to emulate human intelligence for complex predictions and decision-making in the healthcare sector is apparent. Convolutional neural networks (CNNs) and artificial neural networks (ANNs) have shown several applications in dentistry. This technology's prospective applications were analyzed concerning scheduling, patient care, medication interactions, prognostic diagnosis, and robotic surgery [18]. However, prior to the incorporation of AI models into standard clinical procedures, it is essential to do more evaluations to determine their cost-effectiveness, dependability, and appropriateness. Artificial intelligence has the potential to transform the medical and dental fields by providing answers to several clinical challenges, hence enhancing the efficiency of healthcare professionals. The incorporation of AI in the dental sector is not yet widespread [19].

4. Artificial Intelligence in Diagnostics and Radiology

Chen et al. [18] used convolutional neural networks (CNNs) to enumerate and subsequently recognize teeth in intraoral periapical films. The model's precision was exceptional. The computation of precision and recall on a test dataset entail ascertaining the intersection-over-union (IOU) metric between the detected and true items. The results demonstrate that both accuracy and recall metrics exceed 90%, and the average intersection-over-union (IOU) value between recognized units and ground truths also reaches 91%. The study's results indicated that AI technologies optimized the healthcare process. They may bypass manual data entry. Automated solutions allow dentists to efficiently input dental charts digitally, therefore saving time and effort.

Lee et al. [19] described the use of CNN algorithms for the detection and diagnosis of dental caries on periapical radiographs, illustrating the effectiveness of AI technology in this domain. The accuracy of models depicting premolars, molars, and combined premolars and molars was determined to be 89.0% (confidence interval: 80.4–93.3), 88.0% (confidence interval: 79.2–93.1), and 82.0% (confidence interval: 75.5–87.1), respectively. The application's outcomes were quite amazing. Research using deep learning models for the identification and localization of dental lesions in near infrared transillumination (NILT) images has shown promising results, as demonstrated in the study of Casalegno et al. [20].

The research achieved an average intersection-over-union (IOU) score of 72.7% for a 5-class segmentation challenge using a constrained dataset of 185 training samples. Additionally, the particular IOU scores for proximal and occlusal carious lesions were determined to be 49.5% and 49.0%, respectively.

Talpur et al. [21] used deep learning methods in research to analyze dental images for identifying dental caries, which include proximal, occlusal, and root caries. The Neural Network Backpropagation method, a deep learning technique, achieves a maximum accuracy of 99%. Research conducted by Hung et al. [22] has shown favorable outcomes on the use of AI in predicting root caries. Among the several machine learning algorithms created, the support vector machine algorithm demonstrated the greatest performance level. The accuracy rate was 97.1%, the precision rate was 95.1%, the sensitivity rate was 99.6%, and the specificity rate was 94.3% in the successful identification of root caries patients.

Schwendicke et al. [23] have shown the robust efficacy of AI-based models for diagnosing dental caries by the use of NILT images. The incidence of carious lesions at the tooth level was shown to be 41%. The sensitivity and specificity values were documented as 0.59 (95% CI: 0.47–0.70) and 0.76 (95% CI: 0.68–0.84), respectively. The visual analysis of the model's predictions revealed that it demonstrated sensitivity to areas affected by carious lesions. The study's findings demonstrate that the moderately deep CNNs had a commendable selective ability to identify caries lesions.

Hiraiwa et al. [24] described the use of CNNs for detecting single or additional roots in Cone Beam Computed Tomography (CBCT) images and panoramic radiographs of 760 mandibular first molars from 400 individuals. The research included the segmentation of root image patches from panoramic radiographs, then used in a deep learning framework. The primary objective was to assess the diagnostic efficacy of this method in categorizing root morphology. Additional roots were identified in 21.4% of distal roots according to the examination of CBCT images. The deep learning system had a diagnostic accuracy rate of 86.9% in identifying the existence of additional roots in distant roots, compared to a single root.

When applied to panoramic dental radiographs, the convolutional neural networks (CNNs) created by Ekert et al. [25] effectively identified apical lesions (ALs). The positive predictive value (PPV) was 0.49 (standard deviation = 0.10), whereas the negative predictive value (NPV) was 0.93 (standard deviation = 0.03). The research indicated that molars had a markedly higher sensitivity compared to other dental kinds, although specificity was somewhat diminished.

Murata et al. [26] used a deep learning algorithm to examine panoramic radiographs for indications of maxillary sinusitis. The diagnostic performance of this system was adequate. The deep learning system demonstrated exceptional diagnostic performance in identifying maxillary sinusitis on panoramic radiographs, with an accuracy rate of 87.5%. The system exhibited a sensitivity of 86.7% and a specificity of 88.3%. These results were similar with the work of Kim et al. [27] when compared to the performance of experienced radiologists.

Lee et al. [28] evaluated the capability of artificial intelligence to identify and diagnose osteoporosis. Researchers evaluated a CAD system using a deep CNN via panoramic radiographs and found it to be extremely successful in identifying osteoporosis. The CAD system's performance was much superior to the detection rates of expert oral and maxillofacial radiologists. Lee et al. [29] had similar results in detecting osteoporosis using deep convolutional neural networks on dental panoramic X-rays.

5. Artificial Intelligence in Endodontics

Endodontists depend significantly on the analysis of diagnostic imaging, such as intraoral radiographs, cone beam computed tomography scans, and orthopantomography images, for treatment planning and diagnosis. Convolutional Neural Networks (CNNs) with multiple layers may be advantageous for analyzing X-ray images through AI, as this approach concurrently validates adaptive image features and conducts image classification, thereby obviating the necessity for predefined image indicators to calibrate the identification process [30]. Root canal treatment may be conducted non-surgically if dentists possess knowledge of root morphologies and root canal anatomy. Besides detecting errors in canal mapping, AI can identify morphological irregularities.

Automated three-dimensional tooth segmentation was achieved by the CNN approach by Lahoud et al. [31]. The researchers examined 433 CBCT radiographic segmentations of teeth to establish a rapid, efficient, and dependable clinical standard; they discovered that AI matched the performance of a human operator but at a much-accelerated pace. The diagnostic efficacy of lesions and the Dice coefficient indices for multilabel segmentation were assessed between a morphologically restricted Dense U-Net and existing clinical image analysis techniques as reported by Zheng et al. [32]. The researchers found that the distinctive deep learning method enhanced CBCT segmentation and the precision of abnormal identification, notwithstanding the restricted sample size.

Teeth that have had endodontic treatment seldom produce vertical root fractures (VRFs). Determining radiographic VRF is complex and may need advanced techniques. Fukuda et al. [33] proposed that CNNs are an effective approach for identifying and measuring VRFs on panoramic radiographs. Kositbowornchai et al. [34] used a probabilistic neural network architecture to achieve a prediction accuracy of 95.7% regarding the health status of a tooth root, specifically distinguishing between healthy roots and those with a vertical root fracture.

In doing root canal treatment, selecting a suitable working length (WL) is essential. Insufficient working length estimation often results in equipment extending beyond the apical foramen, exacerbation of symptoms, periapical foreign body responses, and inadequate microbiological control [35]. Radiography, digital tactile perception, and patient reactions to a file or paper point are all effective methods for identifying the apical foramen and establishing the working length (WL) [36]. The use of digital technology has shown both benefits and drawbacks in identifying the apical foramen. Given these results, it is advisable to suggest the use of AI for verifying working length and detecting the apical foramen by novice dentists or those without endodontic specialty during root canal procedures.

A recent systematic analysis indicates that the accuracy of AI in diagnosing vertical root fractures varies between 73.6% and 96.6%, with even greater accuracy shown when AI is used on CBCT data for untreated root canals [37]. In diagnosing root fractures inside obturated root canals, AI applications provide much superior performance compared to conventional radiography [37]. The AI root fracture detector's performance on panoramic pictures was characterized by a recall of 0.75, an accuracy of 0.93, and an F-measure of 0.83 [33].

In research by Setzer et al. [38], deep learning segmentation for detecting periapical lesions had a detection accuracy of 0.93. An automated periapical lesion classification system using convolutional neural networks achieved an accuracy of 70% [39]. The accuracy was greater for datasets with photos including big lesions and those devoid of lesions compared to datasets with minor lesions and those without lesions. The analysis of panoramic images by a convolutional neural network has shown good accuracy and sensitivity (84.37 ± 2.79 and 81.26 ± 4.79, respectively) in identifying a damaged endodontic file inside the root canal [40].

A significant use of AI in endodontic regeneration therapy is its ability to evaluate stem cell viability and survival [28]. Pulp stem cells grown in human platelet lysate had superior vitality compared to those cultured in fetal bovine serum or human platelet-rich plasma, as shown by a study using a hybrid machine learning approach [41]. Endodontists now focus on developing artificial intelligence-guided procedures for the regeneration of tooth pulp stem cells for potential therapeutic applications [42]. At now, AI models need to be regarded as auxiliary instruments to enhance the decision-making process in endodontic practice. The education of prospective endodontic specialists may be enhanced by the use of AI capabilities.

6. Emerging Trends and Patterns

Artificial intelligence (AI) offers significant promise in medicine and dentistry. Acquiring a comprehensive and exact picture of our patient's health and issues would enable the more accurate distribution of treatments based on forecasts. Enhanced precision and personalized treatment with increased effectiveness and safety are achievable. Moreover, AI can facilitate the provision of services with enhanced scale and efficiency, using a more varied workforce; this might significantly alleviate global labor shortages and expand access. This analysis determined that most current applications of artificial intelligence (AI) in dentistry are limited to prototypes for automated diagnostics, especially in dental imaging and radiology, as well as classification tools for periodontally compromised teeth or caries [43,44].

An increasing number of dental fields, including prosthetics research, are using AI for enhanced data processing efficiency. The simplicity of importing digitally coded pictures into AI systems facilitated the first applications of AI in dentistry, namely in dental image classification and data processing from area scanning methods. The diagnostic applications of AI are undergoing refinement. Future advancements in patient-centered tailored treatment may be enhanced by the use of AI technology in dentistry, which may become pivotal in the triad of patient data management, healthcare apps, and services.

The integration of AI and precision medicine can radically revolutionize the medical sector. Artificial intelligence enhances the inherent intellect of clinicians via sophisticated computation and inference, offering insights that facilitate knowledge acquisition and empower physicians in decision-making. Personalized diagnoses and prognoses are facilitated by integrating data from patient's symptoms, clinical history, lifestyle, and genetic information. Recent literature indicates that translational research examining this confluence will address the most formidable obstacles confronting precision medicine [45].

The development and use of AI in healthcare are driven by the digitalization of health data and the rapid acceptance of technology. The implementation of AI in healthcare may be obstructed by challenges such as the multidimensional integration of information, safety concerns, federated learning (which requires significant advancements in areas such as privacy, large-scale artificial intelligence, and distributed optimization), model performance, and bias [46]. Furthermore, it would be intriguing to integrate artificial intelligence with smartphone apps or computer software to facilitate the assessment of the dependability of AI-based systems in routine clinical practice [47,48].

Recent research indicates that AI has significant promise in the medical domain. AI is likely to have a progressively significant role in healthcare, affecting both individuals and populations, with initiatives in progress to address challenges in this domain [49]. Prior studies have associated AI with fields of dentistry outside prosthodontics. Radiologically driven AI assessments may identify root fractures, periapical illnesses, and root morphology, facilitating tooth preservation [50-52]. AI technology predicts clinical and radiographic periodontal factors, facilitating the assessment of disease development in periodontology. AI may evaluate radiological images in oral surgery to detect pathological changes such as cysts and bone cancers [53]. Additionally, AI may be applicable in the domain of implantology. AI-driven treatment planning in computer-aided design (CAD) and computer-aided manufacture (CAM) for implant dentistry might significantly enhance the efficiency of virtual 3D treatment planning and, ultimately, facilitate the robotic placement of dental implants [54].

In this era of prevalent illnesses, several adolescents are impacted by oral health problems. Early diagnosis, prevention, and treatment of these disorders are essential for optimal child health. The advancement of artificial intelligence (AI) has significantly intensified in recent years. Consequently, we see AI's encroachment into areas formerly considered exclusive to human experts. The necessity for dental professionals skilled in administering treatment methods and providing suitable counseling on patient behavior is especially pronounced in pediatric dentistry [55]. It can now be unequivocally said that AI will never completely replace dental professionals or pediatric dentists; nonetheless, it will serve as a significant benefit across all dimensions of oral health, including prevention, restoration, and diagnosis.

7. Conclusions

The future of dentistry seems promising, with the forthcoming integration of AI-driven equipment being highly anticipated. AI can transform and innovate processes across dentistry; nevertheless, the integration of AI technology in prosthodontics is presently sluggish. AI systems excel at executing repetitive tasks and processing large volumes of data for classification. AI algorithms are anticipated to assist in the analysis of individual patient situations and facilitate evidence-based dental decision-making, particularly for less experienced practitioners. It may be feasible to provide more standardized treatment procedures that allow for personalization.

Despite its considerable promise, the obstacles encountered by AI systems cannot be overlooked. This complete literature evaluation indicates that the studies should be considered exploratory and experimental, and the methodologies used in these research initiatives are not yet suitable for routine clinical application in prosthodontics.

The principal uses of AI in dentistry are now in undergraduate education and research. Prior to the use of these technologies in routine dentistry, it is essential to enhance the underlying technology and user interfaces. Several essential intermediary stages must be accomplished before the widespread use of AI. Future studies on AI technology in reconstructive dentistry should thoroughly examine both the technological capabilities and the financial ramifications, as well as the ethical considerations.

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تعزيز إدارة الأدوية في طب الأسنان من خلال الذكاء الاصطناعي: مراجعة شاملة لمساهمات التمريض وطب الأسنان والصيدلة

الملخص

الخلفية :إن دمج الذكاء الاصطناعي (AI) في الرعاية الصحية، لا سيما في إدارة الأدوية في طب الأسنان، يملك القدرة على تعزيز فعالية العلاج وتحسين نتائج المرضى. ومع تزايد انتشار أمراض الأسنان ونقص المهنيين، تبرز الحاجة إلى حلول مبتكرة لتحسين تقديم الرعاية.

المنهجية :تحلل هذه المراجعة تطبيقات الذكاء الاصطناعي في مجال طب الأسنان، مع التركيز على الأدبيات المنشورة بين عامي 2000 و2021. تم استخدام قواعد بيانات رئيسية مثل PubMed و Web of Scienceلجمع الدراسات التي استخدمت نماذج الذكاء الاصطناعي، خاصة الشبكات العصبية الالتفافية(CNNs) ، لتشخيص حالات الأسنان وإدارة الأدوية.

النتائج :تشير النتائج إلى زيادة كبيرة في الأبحاث المتعلقة بالذكاء الاصطناعي ضمن مجال طب الأسنان، حيث أبرزت فعاليته في تحسين دقة وكفاءة التشخيص. أظهرت نماذج الذكاء الاصطناعي دقة عالية في تحديد تسوس الأسنان وأمراض اللثة وغيرها من مشاكل صحة الفم. وتشمل التطورات البارزة أنظمة مؤتمتة لتحليل الأشعة ودعم اتخاذ القرارات السريرية، مما ساهم في تبسيط سير العمل وتقليل العبء على المهنيين.

الخلاصة :يمتلك الذكاء الاصطناعي قدرة تحوّلية في إدارة الأدوية في طب الأسنان من خلال تسهيل التشخيصات الدقيقة وخطط العلاج الشخصية. على الرغم من أن التطبيقات الحالية واعدة، هناك حاجة إلى مزيد من البحث لتقييم الجدوى الاقتصادية والآثار طويلة الأجل لدمج الذكاء الاصطناعي في الممارسة السريرية. قد يعتمد مستقبل رعاية الأسنان بشكل متزايد على تقنيات الذكاء الاصطناعي لتحسين نتائج المرضى ومعالجة تحديات القوى العاملة.

الكلمات المفتاحية :الذكاء الاصطناعي، إدارة الأدوية في طب الأسنان، الشبكات العصبية الالتفافية، دقة التشخيص، الابتكار في الرعاية الصحية.