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Review Article

The Role of Artificial Intelligence in Dentistry: A Narrative Review

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ABSTRACT

Integration of artificial intelligence in dentistry has transformed the way dental professionals diagnose, plan treatment, and manage patient care. AI technologies, such as machine learning and deep learning, enhance precision, efficiency, and effectiveness in dental practices to produce better outcomes. This review discusses the broad applications of AI in various fields of dentistry, which range from diagnostic imaging, prediction of treatment, restoration care, orthodontic practice, endodontics, and preventive care. In diagnostic imaging, for example, AI-based techniques such as CNNs significantly enhanced the ability to diagnose dental pathologies, for instance, caries, periodontal disease, and oral cancers, most of which are diagnosed at much earlier stages than with traditional approaches. These methods allow for fewer mistakes, better outcomes, and overall, a greater value for predictive modeling, and especially, treatment planning. Predictive modeling and treatment planning, along with outcome-driven analytics, are changing the formulation of prognosis and modeling of treatment, along with algorithms such as ANN. AI is an imperative core for restorative and prosthetic dentistry. Crown and denture design has significantly benefited from generative design algorithms and other automated design tools. Individualized prosthetic dentures and crowns that fit and are comfortable as well as aesthetic have advanced design. These AI tools in orthodontics and endodontics are also augmenting treatment precision by simulating tooth movements and success predictive modeling for techniques like root canals. The improvements that AI can and will offer dentistry as a whole are numerous. The challenge of implementing AI is widespread. Data privacy and the high cost of adopting advanced technologies are the core issues. The full potential of AI can and surely will augment the care of practice in augmenting AI in Dentistry.

Keywords: Artificial Intelligence (AI), Diagnostic Imaging, Predictive Modeling, Dental Treatment

BACKGROUND

Most human activities now corelate with the use of AI technology, and Dentistry has been one of the areas impacted by these innovations the most. Improvements AI technology such as machine learning (ML) and Deep Learning (DL) has made in dental diagnostics, prognostics, and patient care has been applied in areas such as diagnostic imaging and patient monitoring [1]. However, the creation of AI is coupled with data protection and the ethical problems it poses numerous gaps and challenges. This literature review consolidates current data from various studies to give an exhaustive account of the role of AI in dentistry; AI is posited to be one of the most effective ways to address the challenges of patient care in dentistry. AI technologies such as ML and DL have been around for close to a decade now and have improved their capabilities in handling complex data sets, and clinical decision-making processes have been improved greatly.

For example, CNNs and ANNs have outperformed other algorithms in diagnostic imaging and predictive modeling, respectively [3]. This allows for the early identification of pathologies and the tailoring of treatment strategies to optimize workflow efficiency [4]. There is a wide range of applications of AI in dentistry, including diagnostic imaging, endodontics, orthodontics, restorative dentistry, and public dentistry [5]. AI diagnostic imaging tools have demonstrated accuracy in detecting dental caries, periodontal disease, and some cases of oral cancer. Predictive modeling assists the clinician in formulating a treatment plan, while generative algorithms can facilitate the design of a customized prosthesis [6, 7]. The purpose of this review is to evaluate the applications of AI in dentistry and the associated challenges, and potential directions for the future. This research aims to synthesize the findings of the recent studies to strengthen the argument for improving patient care and addressing the challenges of contemporary dental practice.

REVIEW

AI in Diagnostic Imaging

Other branches of medicine have not been the same as wherein the use of AI in diagnostic imaging in dentistry. There is greater imaging use and there have been even greater advancements in AI used as applied in diagnostic imaging in dentistry. More specifically, the imaging Convolutional Neural Networks (CNNs) used have greatly improved in recognition. Automatically identifying images, CNNs have been very important in the recognition and diagnosis of dental pathologies that would otherwise be very difficult to detect. AI image analysis has been shown to assist in the recognition of periapical lesions and has been shown to assist in the diagnosis of carious lesions and periodontal disease to help the clinician arrive at a correct diagnosis. [8,9].

There have been some recent studies by Miladinović M et al. [4] as the first to demonstrate how the conjunction of certain imaging techniques like CBCT and the use of CNNs can lead to the detection of radiolucent lesions to a certain degree of sensitivity whereby improved diagnosis and treatment plans are possible [10]. It has been shown that AI can help streamline tasks in a workflow and has been able to reduce human error thereby giving a more reliable diagnosis [11] [Figure 1].

Predictive Models for Treatment Planning

There have been advancements in the forecasting capability of artificial intelligence that improve planning in dental treatment. Thanks to the predictive capabilities of artificial neural networks, clinicians can develop individualized treatment itineraries based on predicted outcomes. As Bini et al. [5] explained, ANNs correctly estimated the success probability that could be attained after performing an endodontic procedure. This form of AI also predicts success during the implant phase of Prosthodontics. Predictive modelling algorithms in dentistry provide valuable assistance to assess the morphological aspect of teeth.

Hence, we customize orthodontic treatments and find the most optimal position for the implants. With this kind of predictive tools, clinicians are able to prepare extensive treatment plans with greater assurance in the forecasted results. This specific approach would guarantee the patients would receive treatments that are likely to be successful, enhance the quality of care, and reduce the risks involved [12]. [Figure 2].

Advancements in Restorative and Prosthetic Dentistry

AI improvements have proven quite useful in restorative dentistry, where high precision is needed, especially in the procedure. One is able to measure and quantify very precisely, and this is necessary in designing a restoration and bettering the process. AI image analysis tools help design and measure precision, and this is very useful in the dentistry field to create and better the process. Personalized dentistry is the design and production of

dental prostheses such as crowns and dentures. Studies state that personalized dentistry is useful and provides better outcomes to patients with the use of AI design [13].

In addition, the automated technology assists in the digital scans used to formulate unique restorations to improve. When both the patient and the doctor can access the procedure, the chances of a mistake occurring in the procedure reduce. These interventional methods are more patient-centered as well. Because of this, the AI customization that is used in dentistry is more useful and enhances the comfort and the look of the restorations [14]. [Figure 3].

AI Applications in Endodontics and Orthodontics

AI has transformed endodontic practice in diagnosis to yield more accurate disease diagnosis, including root fractures. According to Sawhney et al. (2024) [5], ML algorithms were highly effective for diagnosing cases of VRF, which often escaped detection by conventional radiographic methods.

AI can interpret the complex data received from images with increased precision, so that one is able to understand better and reduce invasively related extractions. Further, AI-based models help to predict dental issues; consequently, they allow intervention during the progression of a case, ensuring better improvement for the patient [15].

In orthodontics, AI models simulate improvement in treatment, predict the movement of teeth, and create a treatment plan for an individual patient. This capability enhances patient engagement as they can visually see the trajectories of treatment and the expected outcomes. Predictive models optimize the planning of practitioners and allow them to make real- time changes to treatment strategies to make sure that orthodontic interventions are in close agreement with the needs of each patient [16] [Figure 4].

Community Dentistry and Preventive Care

Apart from patient-centered care, applications of AI in dentistry are also seen in community dentistry, most particularly in screening and preventive care programs. Bini SA mentioned that AI may be applied in screening. large populations for oral risks, where he said that AI is the key to preventive dentistry [17]. Rapid assessment of vast amounts of data by AI- based tools can identify populations at high risk and very early signs of many diseases, such as oral cancer, which can be treated with targeted preventive measures [18].

Except for risk assessment, AI-based algorithms in community dentistry enable personalized preventive care. Such developments enhance public health in general while minimizing burdens on dental care systems: potential problems are prevented to begin with.

These systems also offer outreach to underserved populations, helping to close gaps in the access of dental care [Figure 5].

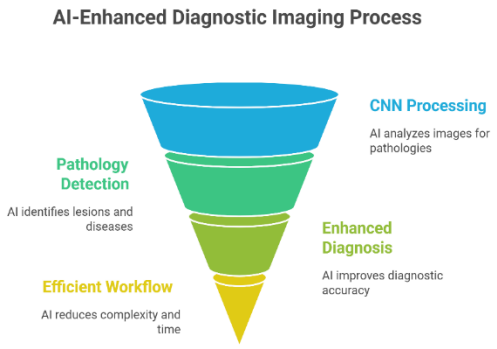

Figure 1: Role of AI in Diagnostic Imaging

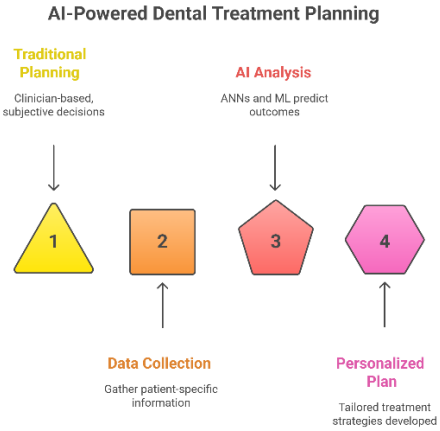

Figure 2: AI-Powered Dental Treatment Planning

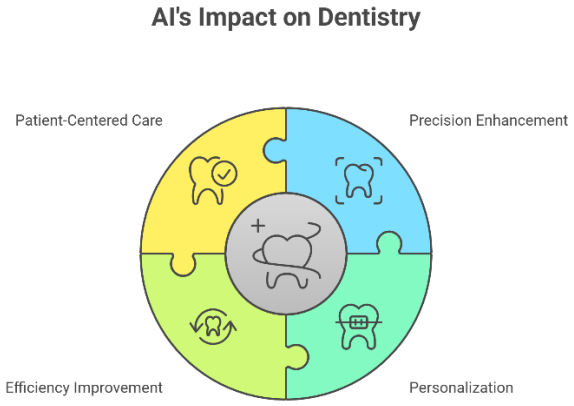

Figure 3: Artificial Intelligence Impact on Dentistry

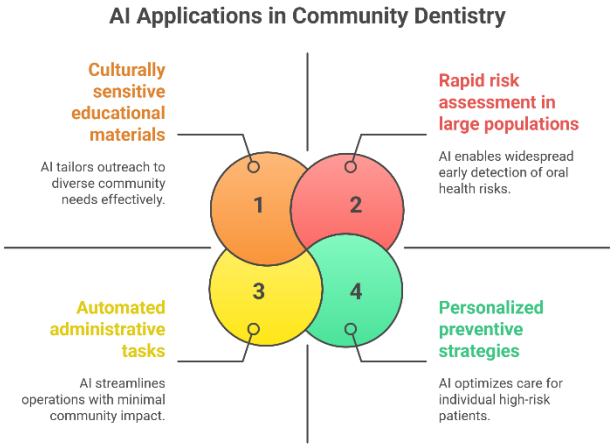

Figure 5: AI Applications in Community Dentistry

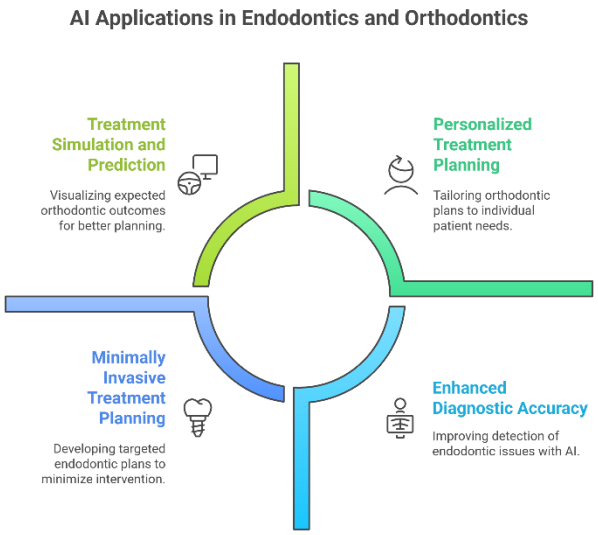

Figure 4: AI Applications in Endodontics and Orthodontics

DISCUSSION

This review delivers diagnostic imaging using convolution neural network technology, one of the most accurate and efficient methods in the healthcare sector, and showcases the AI revolution in dentistry.

AI facilitates the early diagnosis, and consequently the successful treatment of several dental ailments, and the predictive model ANNs assist in the generation of custom treatment plans aimed at personalized, practice-based medicine; however, several hurdles still remain on the surface [19].

The leading obstacles are considerable amounts of data required to train AI systems and data confidentiality. Notably, the "black box" phenomenon where the operations of the system remain unknown to the user. Additionally, the limited financial means available to healthcare AI systems further challenges their accessibility [20].

Regardless of the possible impact of Artificial Intelligence (AI) incorporation into dentistry, there exists a variety of problems involving the privacy of data and, more importantly, loss of data security. It is a fact that effective AI mechanisms function optimally through access of personal data of a number of patients. Such a concern has the potential for data loss. This situation is compounded by worrying legal boundaries, such as the General Data Protection Regulation (GDPR) and the rest of the similar statutes that have inflexible and unreasonable legal obligations on data privacy. Additionally, obtaining data on a disparate model is necessary; obtaining data on demographics is complex, and hence expanding data sources is required [21].

The financial concerns surrounding the adoption of AI technologies are also significant. The initial expenses of AI systems and the even larger financial costs of maintaining and updating the systems are going to be outside the scope of some dental practices. The expenses are going to be climbed from the updates of the systems to the expenses from the updates of the systems to meet the advancement of AI [22].

The next focus of research should be on building more transparent and explainable AI models. More collaborative efforts should be directed towards the design of clinically integrated, user-friendly systems to be used in dentistry. In dental practices, the increased adoption of AI technology will also aim to address ethical concerns, standardization of processes, and cost [23].

Improved ethical concerns, standardization of processes, and cost control will also serve as the most important parameters in promoting the adoption of AI in dentistry [24].

CONCLUSION

The incorporation of AI into the field of dentistry is relatively new and is beginning to change the delivery systems in healthcare technology. AI technology is now used in dental practices like endodontics, orthodontics, and dental public health. Optimum operational functionality in any practice is tied to the precision of diagnostics, predictive analytics, and streamlined procedural workflows. AI, like any technology, faces real world problems such as high costs for implementation as well as little transparency in the models used and concerns of privacy which slow the progress of systems aimed to optimize the delivery of healthcare in real time. Getting the systems to operate in a balanced and effective manner within the ethical and clinical soft limits so that the most can be harnessed from the technology is of utmost importance. AI systems need to be designed so that AI is a value-adding technology with systems that augment human performance rather than designing systems that replace human factors altogether. The balance between the costs of developing such systems and the need to continue system design to improve transparency and costs while increasing accessibility to such systems will define the future.

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AUTHOR CONTRIBUTIONS:

a) **Rujuta Vardhe**: Developed the initial idea for the review, did an analysis and review of the pertinent literature, and then was the main person who prepared the first complete draft of the manuscript, and then revised it multiple times. Additionally, she helped to organize the review article and was the first to discern the major trends about the role of AI in Dentistry.
b) **Snehal Valvi**: Assisted in the collection and literature review on the specific sub area of AI in Dentistry for diagnostic imaging and treatment planning. She also wrote part of the manuscript and was mainly in charge of the discussion.
c) **Supriya Vyavahare**: Contributed in the methodology part of the review by selection of main databases and studies, and the quality assessment of the final chosen studies. She also contributed to the analysis of the manuscript where she highlighted areas that required major changes.
d) **Mehul A. Shah**: Oversaw the entire review, systematized and directed the integration of the evidence on a macro level, and was the editor for the entire manuscript. He was also responsible for the incorporation of changes on the final draft of the manuscript.

ABBREVIATIONS USED IN THE STUDY:

a. **AI** - Artificial Intelligence
b. **ML** - Machine Learning
c. **DL** - Deep Learning
d. **CNN** - Convolutional Neural Networks
e. **ANN** - Artificial Neural Networks
f. **CBCT** - Cone Beam Computed Tomography
g. **GAN** - Generative Adversarial Networks
h. **VRF** - Vertical Root Fracture
i. **PDT** - Predictive Modeling
j. **CAD/CAM** - Computer-Aided Design/ Computer-Aided Manufacturing

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