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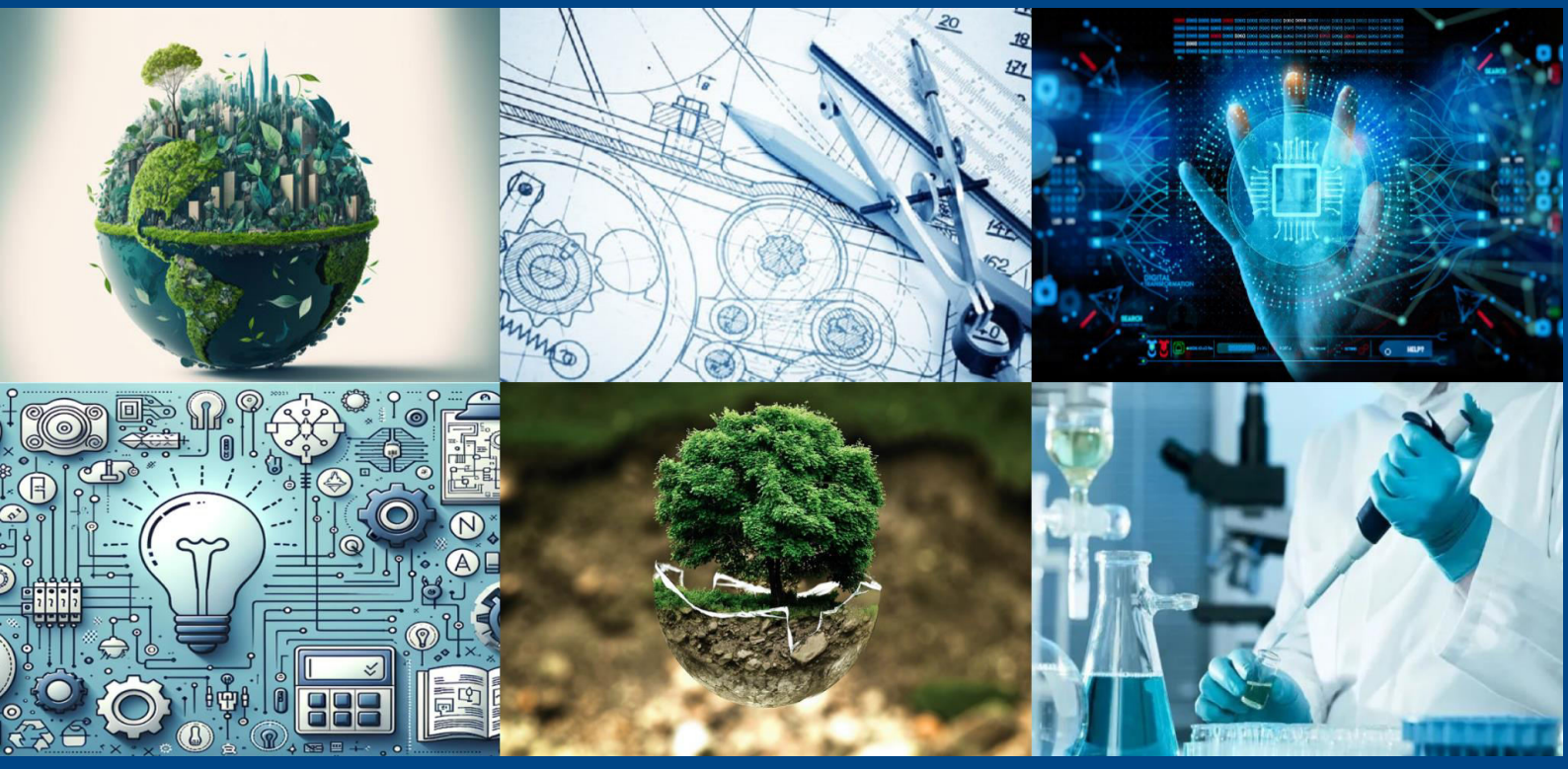

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Artificial Intelligence in Endodontics: A Review

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ABSTRACT: Artificial intelligence (AI) is increasingly transforming diagnostic and treatment approaches in the field of endodontics. The present review discusses the applications of AI in endodontics. Convolutional & artificial neural networks have shown promising applications in root canal anatomy analysis, periapical lesion detection, working-length determination, treatment outcome prediction, and identification of dental pathologies. AI also demonstrates high accuracy in CBCT image analysis. By automating repetitive tasks and providing rapid analysis of complex clinical data, AI may improve efficiency, consistency and decision making in endodontic practice. Hence, in the near future, AI may significantly influence endodontic workflow, dental education and professional learning.

KEYWORDS- Artificial intelligence, Endodontics, Convolutional neural networks, Artificial neural networks, CBCT.

I. INTRODUCTION

Artificial intelligence (AI) is transforming healthcare by integrating computational technologies with human intelligence to perform tasks that traditionally require human reasoning. Since its formal establishment in the 1950s during the Dartmouth Summer research project on Artificial Intelligence, it has evolved into an important component of modern healthcare, with significant potential to improve diagnostic accuracy, treatment planning, and clinical decision-making[1]. Artificial intelligence (AI) has significantly transformed the field of dentistry, with its applications extending across diagnosis, treatment planning, and clinical decision-making[2,3]. AI applications, including convolutional neural networks (CNNs) and artificial neural networks (ANNs), have diverse applications in dentistry. They assist in diagnosis, treatment planning, and clinical decision-making across various dental specialties. In oral and maxillofacial surgery, AI supports dental implant planning and tumour diagnosis, while in prosthodontics it aids in designing aesthetic restorations. In orthodontics, AI facilitates radiographic analysis, cephalometric landmark identification, and malocclusion prediction. Additionally, AI has applications in forensic odontology, dental radiology, periodontics, and endodontics, contributing to improved diagnostic accuracy and personalized patient care[2,3].

Artificial Intelligence IN ENDODONTICS

The rapid advancement of artificial intelligence (AI) has demonstrated significant potential to improve patient care in endodontics. In particular, the application of convolutional neural networks (CNNs) has enhanced diagnostic accuracy and supported more effective treatment planning[4]. For instance, CNNs have demonstrated promising applications in endodontics, including the assessment of root canal morphology, determination of working length (WL), detection of vertical root fractures (VRF), prediction of instrumentation-related forces and torque, and identification of subtle pathological changes on radiographic images[5]. These advancements enable endodontists to achieve more accurate diagnoses and develop individualized treatment plans, thereby improving patient outcomes. Beyond enhancing diagnostic precision and efficiency, AI supports treatment planning through analysis of patient-specific data and prediction of appropriate treatment strategies. AI-based systems can also minimize procedural errors by providing real-time guidance and identifying potential complications. Furthermore, early detection of endodontic pathologies through AI facilitates

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timely intervention and may help prevent disease progression. The use of AI in endodontics is supported by research evaluating the accuracy and reliability of AI-based diagnostic and treatment tools. In addition, user-friendly interfaces and compatibility with existing dental software can facilitate the integration of AI into routine clinical workflows[6].

APPLICATIONS OF AI IN ENDODONTICS

- PERIAPICAL LESION DETECTION- Diagnosis and treatment planning of periapical lesions can be challenging, particularly when relying on conventional 2D radiographs. Although intraoral periapical radiography (IOPA) and orthopantomography are commonly used, they provide limited representation of the three-dimensional anatomy. CBCT offers greater accuracy in detecting and assessing periapical lesions. AI-based algorithms can further assist in identifying periapical pathology and alveolar bone loss. Studies have demonstrated that AI systems can detect periapical lesions with high accuracy, Orhan et al., reported the accuracy of 92.8% (142/153 lesions). AI has also shown potential in differentiating periapical cysts from granulomas using CBCT images, supporting more accurate diagnosis and treatment planning[7].
- ROOT FRACTURE DETECTION- Vertical root fracture (VRF) is a serious endodontic complication that may require root resection or tooth extraction and is often difficult to diagnose using conventional radiography. AI-based approaches, particularly convolutional neural networks (CNNs), have shown promising potential for detecting VRFs on panoramic, periapical, and CBCT images[7].
- DETERMINATION OF WORKING LENGTH-Accurate determination of working length is essential for successful root canal treatment. Although radiography and electronic apex locators are commonly used, variations in radiographic interpretation may affect measurement accuracy. Artificial neural networks (ANNs) have shown potential in improving working length determination by assisting in the identification of the apical foramen and anatomical constriction[7]. Saghiri et al. reported an accuracy of 96% for ANN-based identification of the minor apical constriction compared with 76% for endodontists using IOPA, suggesting that ANNs may provide a reliable aid for working length estimation[8].
- MORPHOLOGY OF ROOT AND ROOT CANAL SYSTEM- Understanding root and root canal morphology is essential for successful endodontic treatment. Although CBCT provides greater accuracy than 2D radiography, its routine use is limited by radiation exposure. AI, particularly CNN-based systems, has shown promising results in identifying additional roots and canals, assessing root morphology, and performing automated 3D tooth segmentation. Deep-learning models have demonstrated an accuracy of 86.9% in classifying root morphology, indicating their potential to support endodontic diagnosis and treatment planning while reducing reliance on extensive imaging[7].
- RETREATMENT PREDICTIONS- Campo et al. developed a case-based reasoning system to predict the outcomes of non-surgical root canal retreatment by considering clinical risks, benefits, and previous treatment data. The system showed potential for predicting retreatment outcomes and assisting in treatment decisions. However, its accuracy depends on the quality and consistency of the available data. Further research with larger datasets and standardized clinical approaches is needed to improve its accuracy, sensitivity, and specificity[9].
- PREDICTION OF STEM CELL VIABILITY- Bindal et al. investigated the use of a neuro-fuzzy inference system to predict the viability of dental pulp stem cells following exposure to bacterial lipopolysaccharides. The system evaluated stem cell survival under inflammatory conditions and demonstrated potential for predicting cell viability during regenerative procedures. Such AI-based predictive approaches may assist in assessing the outcomes of regenerative endodontic therapies[10].
- ROBOTICS ASSISTED ENDODONTICS- AI guided robotics is an emerging technology in endodontics that aims to improve precision, standardisation and safety during canal preparation and obturation. Robotics systems such as DentiBot and DentBot integrate AI-based imaging, sensors and motion tracking to guide instrumentation and compensate for anatomical variability and patient movement. Pre-clinical studies suggest improved accuracy, reduced procedural errors and greater reproducibility compared with manual techniques. As these technologies advance, I-driven robotics may become valuable clinical co-assistants for improving treatment efficiency, safety and workflow in endodontics[11].

CNN AND ANN IN ENDODONTICS

The combination of convolutional neural networks (CNNs) and artificial neural networks (ANNs) has contributed significantly to the advancement of artificial intelligence applications in endodontics, particularly in image-based analysis and diagnosis. CNNs are a specialized type of neural network that are particularly effective in processing and interpreting dental radiographs and other clinical images. In endodontic practice, CNN-based systems have been explored for determining working length (WL), detecting vertical root fractures (VRFs), and assessing root canal morphology and anatomical variations. These networks consist of multiple layers, including convolutional and pooling layers, which automatically identify and extract relevant features from input images. The extracted information is then processed

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through subsequent layers to recognize patterns and generate predictions. By analyzing complex radiographic features that may be difficult to identify consistently through conventional methods, CNNs can assist clinicians in improving diagnostic accuracy and supporting treatment planning. Therefore, the application of CNNs and ANNs represents a promising approach for enhancing the efficiency, consistency, and precision of endodontic diagnosis and clinical decision-making[12].

CNNs are trained using labeled datasets, enabling them to learn the relationship between extracted features and their corresponding labels through backpropagation and optimization. Different layers, including convolutional, pooling, activation, normalization, dropout, and fully connected layers, work together to extract relevant features and generate accurate predictions. Similarly, advances in artificial neural networks (ANNs) have contributed to the development of AI in endodontics. ANNs have evolved from early linear logic networks to connectionist models and, more recently, spiking neural networks (SNNs), which incorporate principles of biological neural activity[6,13].

Spiking neural networks (SNNs) represent an advanced form of artificial neural networks that more closely mimic the information-processing mechanisms of biological neurons. Different encoding approaches, including rate encoding, paired-pulse ratio (PPR) encoding, and spike-time encoding, allow SNNs to represent and process information based on the timing and frequency of neuronal spikes. These features enable SNNs to effectively capture temporal patterns, recognize subtle changes in input data, and demonstrate greater tolerance to noise. Such capabilities may be particularly relevant to endodontics, where accurate interpretation of complex clinical and radiographic information is essential for diagnosis and treatment prediction. Therefore, SNNs represent a promising area for further development of AI-based applications in endodontic diagnosis and clinical decision-making[6].

II. DISCUSSION

The application of artificial intelligence in endodontics is rapidly expanding. Studies have shown that AI-based neural networks can achieve high levels of precision and accuracy, with some models performing as well as or better than dental specialists in specific diagnostic tasks. Therefore, AI can serve as a valuable supportive tool for clinical decision-making, particularly for less experienced clinicians and non-specialists[7].

AI should be regarded as a supportive tool that assists dentists in managing clinical tasks and analyzing patient information. It can process large amounts of structured data efficiently and support clinical decision-making. However, AI currently cannot fully replicate human reasoning and remains limited in handling complex clinical decisions that require professional judgment and experience[14]. In uncertain clinical situations, the experience and professional judgment of the dentist remain essential, particularly for physical examination, evaluation of medical history, assessment of aesthetic outcomes, and effective patient communication. AI cannot fully interpret patients' concerns, expectations, and emotions, which require human interaction, empathy, and understanding[7].

The integration of AI into endodontics faces several challenges, including limited and non-standardized datasets, variations in imaging protocols, and the lack of transparency of "black box" models, which may affect accuracy and clinician trust. Further clinical validation across diverse populations is needed to establish safety, reliability, and generalizability. Ethical and legal concerns, including patient privacy, informed consent, algorithmic bias, and liability, also require attention. In addition, high costs, limited accessibility, and the need for specialized training may restrict adoption. Seamless integration with existing clinical workflows and user-friendly, explainable AI systems will therefore be essential for the safe and effective use of AI in routine endodontic practice[11].

The future benefits of AI technology in endodontics include improvements in scheduling, patient care, management of drug-drug interactions, prognostic diagnosis, and robotic endodontic surgery. AI has demonstrated accuracy and precision in the identification, assessment, and prediction of diseases. Consequently, AI can meaningfully advance endodontic diagnosis and treatment, increasing the efficacy of endodontic therapies.

III. CONCLUSION

While acknowledging these strides, careful considerations of reliability, practicality, and cost-effectiveness are paramount for the seamless integration of AI into routine endodontic procedures. This will ensure sustained

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advancements in clinical outcomes. It is imperative to recognize the ongoing evolution of AI and to address any associated limitations or challenges to foster its responsible and effective use in the endodontics.

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