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Artificial Intelligence in Endodontics

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Abstract

The dental specialty of endodontics is primarily focused on treating conditions affecting the pulp and periradicular tissues. Physicians frequently deal with patients who present with a variety of symptoms. They also have to evaluate radiography pictures critically in two and three dimensions, make difficult diagnoses and decisions, and administer advanced treatment. In combination with inconsistent treatment outcomes due to non-standard clinical practices and low intra and interobserver agreement for radiographic interpretation, there is an unmet need for artificial intelligence (AI) to provide automated biomedical image analysis, decision support, and help during treatment. While there hasn't been much clinical application of AI in endodontics during the last ten years, studies on the subject have steadily increased. In order to better understand endodontic diseases such periapical lesions, fractures, and resorptions, as well as to predict the outcomes of therapeutic treatments, this review critically evaluates the most recent developments in endodontic AI research. The advantages of AI-assisted diagnosis, treatment planning and implementation, and potential future developments in robotics and augmented reality are covered.

Keywords: Artificial intelligence; diagnosis; treatment planning; periapical lesions.

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INTRODUCTION

Artificial intelligence (AI) is the technology that makes it possible for computers and other devices to mimic human autonomy, creativity, problem-solving, learning, and comprehension. AI-enabled apps and gadgets are able to see and recognize items. They are able to comprehend and react to human words. They are able to pick up new skills and knowledge. Both users and specialists can receive thorough recommendations from them. They are capable of acting on their own, negating the requirement for human knowledge or involvement (a self-driving automobile is a classic example).[1]

Machine learning[3,4]

A subfield of computer science and artificial intelligence called machine learning (ML) is concerned with using data and algorithms to help AI mimic human learning processes and progressively become more accurate.[2,3]

Precision medicine, which predicts which treatment regimens are likely to be effective for a patient based on a variety of patient features and the treatment environment is the most popular use of classical machine learning in the healthcare industry.[2] Supervised learning is the process of using a training dataset for which the end variable (such as the onset of disease) is known. This is necessary for the vast majority of machine learning and precision medicine applications.

Deep learning (DL)[3,5]

A technique in artificial intelligence (AI) called deep learning trains machines to analyze information in a manner modeled after the human brain. Deep learning models are able to generate precise insights and predictions by identifying intricate patterns in images, text, sounds, and other types of data. Automating tasks that normally require human intelligence, like text transcription from audio files or image description, is possible with deep learning techniques.

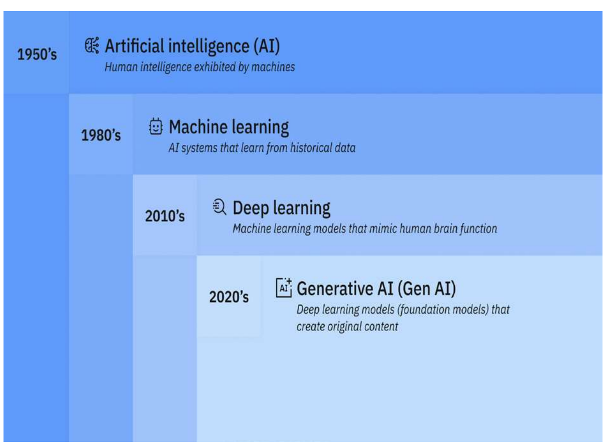

Fig. 1: A comparative perspective of AI, machine learning, deep learning, and generative AI

Natural language processing[6,7]

The automatic analysis, representation, and comprehension of human language is the focus of the computer science and artificial intelligence subfield of natural language processing (NLP).[2] Over the past several years, NLP has gained popularity as a field of study and received a lot of interest from various research communities. Natural language processing (NLP) is crucial to smart healthcare because it allows robots to comprehend human language and communicate with people. Human language is a common type of data entry for intelligent systems.

Artificial intelligence (AI) has a wide range of applications in dentistry, including the detection of dental caries on radiographs[16] diagnosis and treatment planning in orthodontics[17] periodontics[18], prosthodontics[19,20], and smile design automation in prosthodontics. Because AI is so good at identifying minute details in images, like dental radiographs, endodontics may also gain from deep learning[21]. In order to detect periapical pathosis[22,23], vertical root fractures, canal morphology on panoramic and periapical radiographs[24,25], and automate working length determination[26], the majority of AI studies in endodontics used deep learning frameworks. Even with the growing trend of using AI in endodontic research, the majority of endodontists know very little or nothing about the foundations of deep learning and machine learning.

Clinical Applications[8,9]

AI models such as convolutional neural networks (CNN) and artificial neural networks (ANN) are used in endodontics to study root canal anatomy, establish working length measurements, detect periapical lesions and root fractures, determine the success of retreatment procedures, and predict stem cell survival in dental pulp AI models such as convolutional neural networks (CNN) and artificial neural networks (ANN) are used in endodontics to study root canal anatomy, establish working length measurements, detect periapical lesions and root fractures, determine the success of retreatment procedures, and predict stem cell survival in dental pulp AI models such as convolutional neural networks (CNN) and artificial neural networks (ANN) are used in endodontics to study root canal anatomy, establish working length measurements, detect periapical lesions and root fractures, determine the success of retreatment procedures, and predict stem cell survival in dental pulp.

Computer Vision in CBCT Scans: Artificial intelligence (AI)-enabled computer vision approaches can help in CBCT scan analysis, pathology identification, anatomical structure identification, and therapy planning.

-Metal Artifact Reduction Filters: AI algorithms can improve the clarity and accuracy of CBCT scan interpretation by mitigating the picture distortion brought on by metallic restorations or implants.

– Diagnosis Support: To help endodontists make precise diagnosis and treatment recommendations, artificial intelligence (AI) models can evaluate information about patients, including radiographic images, history of illness, and symptoms.

Chatbots on Practice Websites: Artificial intelligence (AI)-powered chatbots can instantly respond to patient inquiries, help patients schedule appointments, and give pertinent educational materials, all of which improve patient satisfaction and engagement.

AI has also been used to forecast the outcome of RCTs. An artificial intelligence (AI) model for forecasting the elements linked to root canal treatment failure was described by Herbst *et al.*[51] In terms of forecasting tooth-level parameters, this model performed well. The use of machine learning models for endodontic microsurgery prognosis prediction was reported by Qu *et al.*[58] The performance of the gradient boosting machine (GBM) model was outstanding.

In periapical and panoramic radiographs, artificial intelligence aided in the diagnosis and detection of mandibular C-shaped root canals, segmented teeth and pulp cavities, detected carious lesions and periapical periodontitis with greater accuracy, and identified periapical lesions on radiographs more accurately than radiologists.

Classification[10,11]

Classification is one of the most important jobs for using AI in endodontics, and it is divided into binary (yes/no), multiclass, and multilabel classifications (Fig. 8). For example, assessing whether or not the tooth has a periapical lesion based on radiographic imaging is an example of binary classification (Endres *et al.*, 2020). Multiclass classifications include categorizing the complex internal anatomy of teeth, such as the number and morphology of canals, with the aid of radiographic images, as well as distinguishing between a healthy tooth, a tooth with caries, and a tooth with external cervical resorption (Li *et al.*, 2021; Nosrat, Dianat, *et al.*, 2023). Multilevel classification is the process of identifying numerous labels for each sample at the same time, allowing a single sample to be classified into multiple classes at once, such as a model that detects caries, periapical lesions, and root canal morphology in a single evaluation (Campos & Salvadeo, 2020).

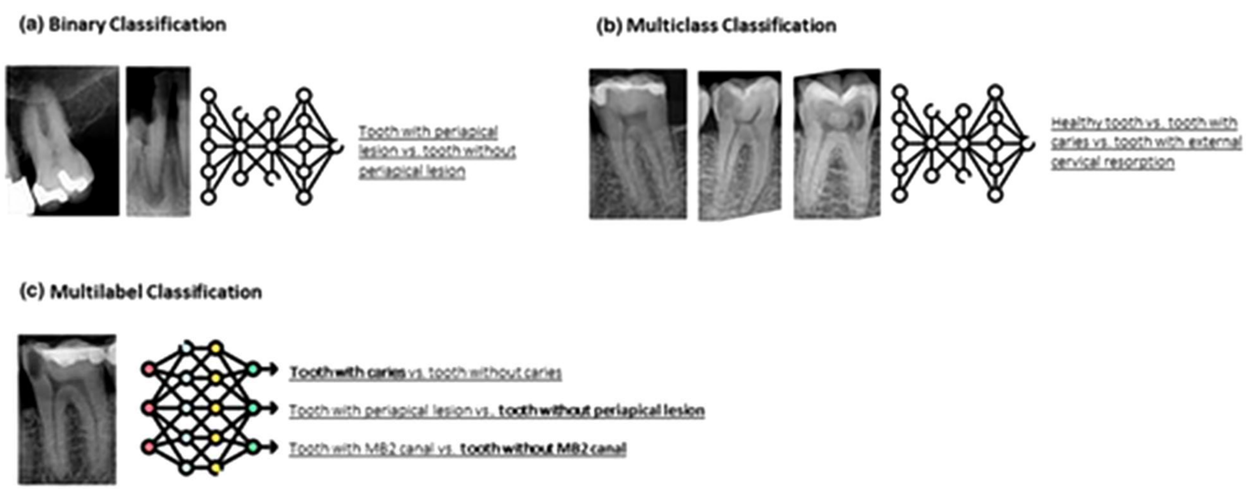

Image source[5]

AI in teaching dental morphology: Augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) can enhance the learning experience by visualizing various anatomical features, tooth forms, sizes, positions, and internal anatomy. Reymus *et al.*[14] investigated the use of VR in tutoring root canal structure and discovered that VR appears to be a beneficial method for training an undergraduate.

AI can give objectivity in diagnosing endodontic illnesses by analyzing aspects and patterns that a human observer may miss, as well as decreasing the subjective bias that physicians introduce into medical picture analysis. If a patient chooses tooth retention after root canal therapy fails, he or she must choose between nonsurgical or surgical retreatment. Histologically, odontogenic PLs might be granulomas, cysts, or abscesses. While the existence of a sinus tract or clinical signs such as swelling, redness, or pain can help detect abscesses, cysts cannot be separated from granulomas either clinically or radiographically.

Detection of Periapical Lesions[7,12]

AI is now being developed to assist clinicians in the localization of periapical pathologies.[6] Setzer *et al.* applied a deep learning system to 20 CBCT volumes containing 61 roots with and without periapical lesions. Each voxel was labeled using AI segmentation as "periapical lesion", "tooth structure", "bone", "restorative material", or "background". This deep learning AI system detected lesions with 93% accuracy and 88% specificity.[7] Other studies have found that AI detection of periapical lesions from both periapical radiographs and CBCT volumes is equal to or superior to those of experienced professionals.[8,9] In the near future, artificial intelligence (AI) may be able to "read" a CBCT scan, alerting the doctor to areas of potential apical pathosis as well as other odontogenic or non-odontogenic lesions found on the scan.

The general pattern in radiologic artificial intelligence studies is that trained CNNs can match or exceed skilled physicians' diagnosis performance when enough basis for fact is available for data labeling. Concerns about the possible AI replacement of radiologists have already arisen due to CNNs' performance on a variety of jobs. Even if it is too soon to say what role artificial intelligence (AI) will ultimately play in diagnostic radiology, it is critical to create rules and ethical frameworks in advance of the clinical application of AI tools.

Prediction of stem cell viability[9,11]

Research on stem cells taken from dental pulp which are used in many restorative treatments was done by Bindal *et al.*[68] A potential foreseeable tool for cell survival after different regeneration methods that are susceptible to microbial invasion is the neurofuzzy inference system.[67,68] following the cells' induction of an inflammatory response by lipopolysaccharide treatment, the pulp stem cells' viability was evaluated. Afterwards, the researchers assessed how well the adaptive neurofuzzy system predicted stem cell survival following microbial invasion.

AI in technician-dentist communication[11,13]

Similar to treatment outcome prediction, AI offers many advantages in terms of design, communication, and cost. Building trust with the patient and making it simpler for them to provide the technician the information they need can both be accomplished by showing them a visual representation of the outcome. These innovative technologies have the potential to boost interaction between the interdisciplinary team, patients, dental assistants, and dentists. An augmented reality gadget can create a three-dimensional model that can be placed directly in the patient's mouth to plan an aesthetic operation. An augmented reality device can display the operator's reality to a dental professional or other specialist while they are designing a treatment plan.

Through individualized and compassionate support, artificial intelligence (AI) has the potential to significantly reduce children's fear of needles and dental extractions. During extraction, AI can take kids too peaceful and interesting virtual worlds through immersive technology like virtual reality, taking their minds off scary situations. Dental practitioners can monitor a child's fear levels and respond with comfort or pauses thanks to AI's real-time emotion recognition capabilities. AI-powered instructional resources can further demystify the extraction process in a way that's kid-friendly, which eases worry and confusion.

AI has been proposed for a variety of applications in dentistry, including diagnosis, dental telemedicine services, decision support, clinical workflow optimization, cost reduction, research support, and teaching improvement (Alhaidry *et al.*, 2023; Eggmann *et al.*, 2023; Sallam, 2023; Suárez *et al.*, 2022). Few researches have examined the responses produced by AI in the field of endodontics. Suárez *et al.* (2022) created an AI chatbot to research pulpal disease in endodontics, leading to improved communication and confidence among students.

Retreatment Predictions[7,9]

Campo *et al.* described the use of the case-based reasoning (CBR) paradigm to forecast the advantages and hazards of nonsurgical endodontic retreatment. In conclusion, the system decided if retreatment was required. The system integrates data from domains including accomplishment, memory, and analytical probability. The system's strength lies in its potential to reasonably predict the retreatment's outcome. One restriction was that the system's usefulness would have depended solely on the information gleaned from the data. CBR is the process of formulating solutions to problems based on previous experiences with related challenges. It is possible to combine crucial knowledge and information by resurrecting similar cases. System heterogeneity may result from the problem of variances and the availability of various techniques.

Caries detection[4,8]

A major field where AI has advanced significantly is caries detection. Accurate carious lesions in dental photos can now be identified thanks to machine learning methods. For example, Ghaznavi Bidgoli *et al.*[15] used an OPG and a standard dataset to autonomously diagnose dental disorders using a CNN in a deep NN architecture. Their method includes determining decaying, root-canaled, and repaired teeth, demonstrating the potential of AI in diagnosing a wide range of dental diseases. In a similar vein, Oztekin *et al.*[25] concentrated on employing pre-trained models and different ML models for dental caries diagnosis. These researches demonstrate the adaptability of artificial intelligence (AI) applications in dentistry, especially in the field of caries detection, where machine learning (ML) models can provide automated and precise diagnoses.

Working Length Determination[3,5]

The accuracy of an ANN's working length determination in a person was examined by Saghiri *et al.* cadaver model designed to resemble a clinical setting. When evaluating an artificial neural networks (ANNs) with an actual measurement made after extraction, they discovered no differences in the root length measurements. They also stated that when it came to determining small anatomic constriction using periapical radiographs, the ANN (96%) outperformed the endodontist (76%). As a result, an ANN is regarded as an accurate working length determination technique.

Consequences of utilizing AI in pediatric dentistry, especially in behavior therapy[6,9,10]

Artificial intelligence may not be able to adequately offer children with the more individualized and compassionate care that they need. In pediatric dentistry, developing rapport and trust is essential, and AI may need to completely handle these emotional components.

A human dentist would be better suited to handle abrupt changes in a child's behavior during a dental procedure than artificial intelligence (AI) technologies.

CONCLUSION

Future endodontic practices will be greatly impacted by AI applications, which could improve accuracy and efficiency while also changing the treatment of patients and practice administration in a number of ways. Although artificial intelligence (AI) technology have the potential to improve some elements of dental treatment, it is important to recognize the complex nature of pediatric dentistry and the special needs of young patients. The use of AI in endodontics continues to be somewhat limited in comparison to other dental specialties, but there are some intriguing areas that show great potential for future expansion. When considering how our field of dentistry will evolve in the future, endodontics is not an exception.

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