



Artificial Intelligence in Endodontics

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ABSTRACT: Endodontics is the branch of Dentistry that focuses on providing quality care in order to preserve the functioning of the natural tooth which prevents any further destruction, leading to extraction. It provides treatment for carious, discoloured, malformed, fractured and unesthetic teeth.

With the advancement in the field of technology and the evolution of artificial intelligence, researchers around the globe have seen newfound interest in the field.

Artificial intelligence is not just limited to the IT sector but has been taken up by other fields as well, and dentistry is no exception. With the huge increase in the digitalization of information and patient data, artificial intelligence is an absolute necessity that can reduce manual work and increase efficiency.

Technology has its feet in every aspect from the basic process of taking history to form a database, to applying various algorithms to achieve the final diagnosis. Though artificial intelligence can act as a supplement to the basic knowledge of the clinician, but in no way can it substitute the clinician. Future goals of AI research in endodontics include not just improving AI model performance to expert levels but also identifying early lesions that are unseen to the human eye. The AI-based comprehensive care system is anticipated to establish high-quality patient care, creative research, and development, and facilitate cutting-edge decision support tools in the future.

Keywords: Artificial intelligence, Endodontics, Technology

I. INTRODUCTION

Endodontic treatment aims to provide the highest quality care to keep the tooth in its functioning state and to avoid any further issues. "It is the branch of dentistry which deals with the treatment of caries, malformed, discolored, unesthetic, or fractured teeth". It deals with treatment of dental pain, periapical and pulpal diseases. Accuracy in clinical decision-making and diagnosis is crucial for getting the greatest results. Numerous diagnostic instruments and treatment modalities have been developed as a result of scientific and technological breakthroughs, opening up new possibilities for detection, decision-making, and optimal therapy design for endodontic disorders. (1-5) In 1956, John McCarthy first developed artificial intelligence which is the branch of applied computer science. (6) Numerous dental applications use supervised learning, in which the training data included many samples with various traits or characteristics (such as patient's images, their demographic data ,

number of caries they have, and so on), and ground truth is determined (e.g., whether there was a previous endodontic visit or not). (6) In order to carry out numerous diagnostic tasks in clinical practice, artificial intelligence (AI) consists of computing models that resemble the human brain. (7)

Artificial intelligence, as defined by Richard Bellman in 1978, is "the automation of processes related to human cognitive abilities, such as learning, making decisions, and solving problems." (8,9) A branch of artificial intelligence called machine learning (ML) uses algorithms to discover the inherent statistical structures and patterns in data, enabling the prediction of yet-to-be-observed data. (10) Artificial neural networks (ANN) are yet another type of AI. (11). In contrast to standard machine learning, this technique evaluates data in terms of input and output while accounting for the weight of factors that impact the input and output. (11,12) Component of neural networks is deep learning in which the data is analyzed on its own with the help of a computer. Deep learning neural networks' buried layer has between a few thousand and a few million neurons. (13) Nowadays, artificial intelligence (AI) is gaining traction in the disciplines of medicine and dentistry. (4,5)

AI is extremely useful in endodontics for identifying vertical root fracture, positioning the apical foramen and calculating working length, predicting periapical pathosis, evaluating root sound structure, retreatment techniques, etc. (14) Endodontics has benefited from advances in digital dentistry since it requires a suitable visualization technique to expose root canal anatomy and periradicular structures using cone-beam computed tomography and digital 2-dimensional (2-D) radiography (CBCT). (15) The use of neural networks to analyze images has slowed down development in recent years. Using periapical radiographs as the input, a deep CNN system performed well in detecting dental cavities. (16)

Future goals of Artificial Intelligence research in endodontics comprise not just improving AI model performance to professional heights but also recognizing initial lesions that are unseen to the naked eye. The AI-based inclusive care system is anticipated to create superior patient care, creative research in addition development, and facilitate cutting-edge decision provision tools in the future. (17)

II. ARTIFICIAL INTELLIGENCE IN ENDODONTICS

Dartmouth University pupils officially suggested the word "artificial intelligence" at a summit in 1956. (18) Artificial Intelligence (AI) is the study of how to make computers execute tasks that could just be performed by humans formerly. (19) It has developed rapidly in recent years, and it has changed people's lifestyles. (20)

AI has the capability to replicate human intelligence to implement, foresee, and judge decisions in medicine and has appreciably expanded its existence and relevance in many tasks and purposes in dentistry, notably endodontics. (21) It can be used in endodontics in various aspects like teaching dental morphology, pre-clinical education, clinical work, dental phobia, dentist-patient communication, dentist-dentist communication, and dentist-technician communication.

III. AI IN TEACHING DENTAL MORPHOLOGY

Anatomy is generally studied by utilizing stationary two-dimensional (2D) illustrations such as presentations, and books. (22) Anatomical forms are three-dimensional (3D), and thus, understanding the 3-D relations applying such static 2D images is challenging. (23)

Through Augmented reality (AR), Virtual reality (VR), and AI different anatomical structures, tooth shapes, size, position, and internal anatomy may be envisioned, creating the understanding experience further immersive. (24) Reymus et al. examined the application of VR in tutoring root canal structure and learned that VR seems to be a beneficial means appropriate for educating an undergraduate. Thus, these may be judged as effective platforms for teaching anatomy and improving the learner's interest. (25)

IV. AI IN PRE-CLINICAL EDUCATION

Conventionally, pre-clinical teaching for dental undergraduates is a blend of theoretical tutoring and practical understanding. (26)

Not long ago, AI has been integrated to build a simulated reality that facilitates recreation of the practical techniques in three dimensions and grants access to clinical and surgical procedures. (27) This approach of teaching lessens the possibility of iatrogenic losses and demonstrates to be more useful, economical, and consistent. (28)

V. AI IN CLINICAL ENDODONTICS

The main focus of AI in endodontics is on using the technology to define the working length, locate apical foramen, estimate retreatments, anticipate periapical diseases, identify and diagnose vertical root fractures, and assess root morphologies. (29)

AI in determining working length and locating apical foramen: A successful endodontic treatment requires determining a correct working length. Traditionally, radiographic procedures, paper point method, digital tactile sensation, (30-32) electronic apex locators and cone-beam computed tomography (CBCT) are being applied for detecting the apical foramen. (33,34)

Recently, many studies have showed that ANNs have been more exact in locating the apical foramen than the above-mentioned methods or have helped in increasing their accuracy. (35,36) A study reported an AI-based prototype being used for verifying the working length on single-rooted teeth on the dry skull and the ANNs showed exceptional results with 93% of exactness. [20] These models can greatly help less proficient dentists and non-specialists as these can be employed in clinical use when there is no accessibility of professionals. (37)

AI in retreatment predictions: Retreatment predictions are being made using case based reasoning (CBR) systems. (38) According to the report of Campo et al. (38) A CBR paradigm having information on statistical probability, performance, and recall was designed for the estimation of the outcome of nonsurgical retreatment of the root canal. The approach recommended on whether to retreat or not. The restriction of this system was that the precision could only fit the statistics in the data. (39)

AI in prediction of periapical pathologies: By using the case history, a clinical examination, and radiographic analysis, dentists must compile all the necessary information to provide a provisional diagnosis before providing the definitive answer. Sometimes a diagnosis cannot be made based solely on a clinical or radiological evaluation. Consequently, it's critical to have a trustworthy tool that can help a dentist make an accurate diagnosis and establish the proper course of action for treatment. (39) Periapical lesions are mostly seen as radiolucencies on radiographs. However, the information given from the periapical radiographs is undependable because the definite 3-D anatomy is condensed into a 2-D image. (40) CBCT imaging is also a 3D imaging technique to accurately detect, locate and measure periapical lesions .

Artificial intelligence is extensively applied in the diagnosis of periapical pathologies. (41-48)

Two prototypes were developed in a study, the first for identifying alveolar bone loss and the second for quantifying the degree of bone loss. (41,42) A deep learning network of neurons was developed based on alveolar bone loss to identify periodontally challenged molars and premolars and predict irretrievable molars and premolars. (43) Mol et al and Carmody et al presented simulations to classify the seriousness of periapical lesions with respect to the diagnosis of periapical pathology. (44,45) Another study stated that a deep learning system model can detect periapical radiolucencies on radiographs as accurately as 24 dentists. (46) As discovered by Orhan et al. (47) 142 out of 153 periapical lesions could be recognized by the AI system, and the recognition accuracy rate was 92.8%. (48) Additionally, Flores et al. developed a technique using CBCT to identify periapical cysts from granulomas; this technique is extremely important in clinical practise since it enables periapical granulomas to heal following root canal therapy without the need for surgery. The recognition of cystic lesions has also been done using ANNs. (48,49)

The authors of a study that used an AI-based model to predict the presence of a periapical lesion revealed some unexpected results, but they also noted that the prototype did not outperform the reference standard and that the results could be improved going forward by using an optimisation procedure. (50)

AI in Detection and diagnosis of vertical root fractures: Vertical root fractures account for 2% to 5% of crown or root fractures, are regarded as a significant consequence that may necessitate either root resection or tooth extraction. (51,52) The detection of a Vertical root fracture, which can be difficult to diagnose, is assisted by radiographs and cone beam computed tomography (CBCT) imaging. A needless surgical operation or tooth

extraction could occur due to a lack of a conclusive diagnosis. The clinical presentation and inadequate sensitivity of conventional radiography to detect Vertical root fractures often restrict a clinician's diagnostic options. (53) In a study conducted by Talwar et al, they found that radiography performed only marginally better than CBCT imaging in detecting VRFs in unfilled teeth compared to unfilled teeth having root fillings. According to Fukuda et al. (54) , Using CNNs (recall 5 0.75 [sensitivity], precision 5 0.93 [positive predictive value], and F measure 5 0.83 [index used to evaluate machine learning performance]), it may be possible to identify VRFs on panoramic radiographs. In a second investigation, vertical root fractures in teeth that were both unfilled and root-filled were identified utilising periapical radiographs and CBCT images. In comparison to images from 2-dimensional radiography, they found that the detection of a root fracture on CBCT images is superior in terms of accuracy, sensitivity, and specificity. (55)

AI in root and root canal system morphology: A dentist must be well-versed in the anatomy of the root canals in order to perform an endodontic procedure successfully. (56) Periapical radiography and CBCT imaging have traditionally been employed for this reason. CBCT imaging has proven to be more precise than radiography at identifying the root and root canal geometries. However, due to radiation issues, it cannot be recommended in routine clinical practise. According to a study, the deep learning system using panoramic radiographs displayed great accuracy in the differential identification of one or more distal roots in the mandibular first molars, whether they were single or multiple roots. Deep learning systems were used to generate learning models by importing image patches that were extracted from panoramic radiographs. (57) The programme created by information analysis and artificial intelligence (AI) showed the capacity to measure the root canal curvature and its 3-D alteration following the use of instruments. (58)

VI. AI IN DENTAL PHOBIA

According to estimates, 50–60% of people have mild to severe dental anxiety or a particular phobia of dental operations and related stimuli (59,60). Fright related behaviours are regarded as the most challenging component of managing dental patients and may obstruct receiving proper dental care since patients who suffer from dental phobia, also known as "odontophobia," only visit the dentist when the clinical situation is critical. (61) The therapies In Vivo Exposure Therapy (IVET) and Virtual Reality Exposure Therapy are seen to be the most successful in treating phobias and fears (VRET). The goal of IVET is to lessen the anxiety response that results from the patient being directly confronted with an object or sequence of uncomfortable events. This exposure therapy is regarded as the benchmark therapy for treating particular concerns associated with receiving dental care. (62) In recent years, VRET has proven to be an effective substitute for IVET in the management of specific phobias. (63) Clinical research has shown that approaches including cognitive behavioural therapy, nitrous oxide, and intravenous sedatives used during dental procedures can lessen patient pain and discomfort. (64,65) In addition, dental pain can be effectively treated using virtual reality as a non-pharmacological analgesic. (66) According to a number of studies, using virtual reality reduced people's awareness of their tooth pain and prevented them from considering it frequently. One benefit of virtual reality may be the patient's inadequacy to see the dentist and their equipment. (67-69) Depending on how patients feel in the virtual environment, the success of virtual reality distraction therapy may vary. (70)

VII. AI IN DENTIST- PATIENT COMMUNICATION

As a result of digital dentistry, many cutting-edge technologies have been developed that can assist in patient-dentist communication. For instance, the use of digital technology has simplified both the process of collecting and storing a series of facial and intraoral shots. This not only makes communication easier, but it also enables the dentist to continue seeing the patient after the consultation by exchanging information with the dental laboratory and other specialists who might assist with the treatments. (71) As diagnostic and virtual wax-up enable for the viewing of potential prosthetic treatments, several gadgets can currently be employed to improve dentist-patient communication. Oral health education initiatives can also be implemented using these technologies. For instance, by making learning fun, teaching kids how to brush their teeth could become more practical, efficient, and available. (72)

VIII. AI IN DENTIST -TECHNICIAN COMMUNICATION

AI has numerous benefits corresponding therapeutic outcome prediction in terms of design, communication, and economics. Giving the patient a visual representation of the outcome can help build trust with them and make it easier to provide the necessary information to the technician. These cutting edge technologies can increase communication between dental professionals, dental assistants, patients, and the interdisciplinary team. For the purpose of planning an aesthetic procedure, an augmented reality device can produce a 3 dimensional model that can be put right in the patient's mouth. When creating a treatment plan, an AR system can show the dental technician or another specialist the operator's reality. (73)

IX. IMPACT OF AI ON DENTISTS

There has been much discussion about how AI can alter dentistry, but it is still unclear whether dentists will ever entirely be replaced by AI. Clinical care does not include dentistry conducted by technology and without human involvement. The clinical intuition, intuitive perception, and empathy that are necessary for providing tailored healthcare and professionalism cannot be produced by machines. It is difficult to transform the most exciting part of human-to-human conversation into computer language. (74)

X. DISCUSSION

With inception of machine learning and other artificial intelligence technologies, the amalgamation of artificial intelligence into the health care sector has accelerated. It is also being utilized to tackle several clinical issues. Lately, there is a significant increase of its use in the field of dentistry with the application of machine learning methods in the field of medicine. (75)

The effectiveness of endodontic therapy is largely based on a number of variables, including thorough examination, clinical judgement, treatment, and post-endodontic care. For the diagnosis and treatment planning of periapical diseases, dentists frequently relied on traditional radiography approaches. AI has recently been used in endodontics to help with diagnosis, determine whether treatment is necessary, and forecast the prognosis. (76) Present study explored the increasing relevance of artificial intelligence in the field of endodontics. Thus, it has summarized the importance of AI in endodontics in various aspects like teaching dental morphology, clinical work, dental phobia and dentist-patient communication etc.

Artificial intelligence helps in imparting a better understanding of dental anatomy and developing pre-clinical skills among dental graduates. This modus operandi tends to be more reliable and efficient. It also plays a major role in endodontics for determining the working length, locating apical foramen and assessment of root morphologies. Hence, increasing the accuracy of the diagnosis and treatment planning.

Communication in dentistry is considered as an essential clinical skill to establish a rapport with the patient leading to effective diagnosis and treatment planning. AI helps in providing a visual representation of the outcome to the patient, thus building trust and a better understanding between the dentist and patient.

XI. CONCLUSION

With the advent of technology, artificial intelligence is no more a myth, but the future reality. Its application is not just based in the world of information and technology but in the field of medicine and dentistry as well. Even though it has profound effect in the field, its use cannot totally replace the experience and the knowledge of the dental practitioners, hence acting only as a supplement not the substitute of the experts of the field.

Knowledge of AI will give practitioners an advantage to cut down on the time, effort, and resources needed for a certain treatment plan. But at the moment, the sole barrier to using AI is the lack of reliable and adequate data. Therefore, it is the clinicians' duty to concentrate on gathering and entering the real data in their database, which will soon be completely utilised for AI in dentistry.

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