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Review Article

Artificial intelligence - A boon for dentistry

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ABSTRACT

Today artificial intelligence (AI) is becoming increasingly important in the healthcare industry. It can be useful in many areas where humans can be aided by new technologies. The concept of "artificial intelligence" (AI) refers to machines being capable of performing human tasks. Machine learning (ML) is an AI subdomain that "learns" intrinsic statistical patterns in data to ultimately make predictions on unseen data. Deep learning is a machine learning technique that employs multi-layer mathematical operations to learn and infer on complex data such as imagery. With the substantial growth in documented information and patient data, intelligent data computation software has become a requirement. Artificial intelligence has a wide range of applications in medicine and dentistry, from data processing and information retrieval to the use of neural networks for diagnosis and the incorporation of augmented reality and virtual reality into dental education. Artificial intelligence (AI) is being studied in dentistry for a variety of purposes, including the identification of normal and anomalous structures, disease diagnosis, and treatment outcome prediction. This review looks at some current and future applications of AI in dentistry. We are ushering in a modern age, and AI is undeniably the future of dental practise management.

1. Introduction

In health care, what seemed like science fiction is now becoming reality. Artificial intelligence (AI) is a rapidly developing technology that allows machines to perform tasks that only humans can do.[1] It is flourishing in healthcare, with traditional dentistry evolving and gradually being transformed into digital dentistry. AI has the potential to significantly improve diagnosis accuracy and revolutionise healthcare. AI research began in 1943, but the term "artificial intelligence" was coined by John McCarthy in 1956 at a conference in Dartmouth.

Artificial Intelligence" is used when a machine mimics "cognitive" functions that humans relate with other human minds, such as "learning" and "problem solving".[2] The father of artificial intelligence, John McCarthy, defines AI as "the science and engineering of creating intelligent machines, particularly intelligent computer programmes.". It enables humans to combine human intelligence with computer technology in order to improve the potential of the healthcare industry to serve better.[3]

As AI technology advances at a rapid pace, we can expect to see a growing impact of AI in dentistry in the future, as it provides enormous benefits to both dental clinics and patients. Furthermore, current research suggests that AI might seriously affect the job markets, as it will replace or repurpose certain professions.[4] AI solutions are increasingly being used to help doctors make decisions in diagnostic suggestions, therapeutic protocols, personalised medicine, patient monitoring and predicting and tracking the transmission of epidemiological diseases. AI applications range from health emergencies, prevention,

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and therapeutic interventions, to patient outcome analytics.[5] Furthermore, AI is expected to bridge the gap between medicine and dentistry in order to investigate and interpret the impact of general disease patterns on oral health.

The AI digital systems have unquestionably changed the direction of dentistry.[6] The AI modalities: machine learning, deep learning, cognitive computing, computer vision (recognizes the content in photos and videos), and natural language processing (to both analyze and generate human speech with the help of machines), are promising and practiced in dentistry.[7] Therefore the purpose of this Review Article is to focus on AI applications that could enhance or alter clinical practice, to provide a historical perspective on AI in modern dentistry to contextualize recent advancements, to summarise successful application areas, to identify the potential societal impact arising from the development and deployment of biomedical AI systems, and to suggest future research directions.

2. Brief Review of AI in Medicine

Medicine was early identified as one of the most enticing AI application areas. Gunn, in 1976 originally explored the potential for using computer analysis to diagnose severe abdominal discomfort in the sphere of surgery.[1] A lot of artificial intelligence (AI) has already been used in the medical field, starting from online appointment scheduling, online check-ins at healthcare facilities, digitization of health records, reminder calls for follow-up appointments and vaccination dates for children and pregnant women, to drug dosage algorithms and adverse effect warnings while prescribing multidrug combinations.

Radiology has been most receptive to the new technology. The use of CAD (computer-assisted diagnosis) in screening mammography is well known. AI could significantly help radiology by not only labelling abnormal exams but also identifying quick negative exams in computed tomographies, X-rays, and magnetic resonance images; particularly in high-volume settings and hospitals with limited human resources.[8] AI's scope has expanded to include therapeutic applications. AI therapy is an online course that assists patients to treat their social anxiety by utilising the cognitive behaviour therapy.[9] Surgical robotics, particularly in urology and gynaecology, are also utilising artificial intelligence. The system's robotic arms, that have a 3D view and magnification options, mimic a surgeon's hand movements with greater precision, allowing the surgeon to perform minute incisions.[10] It is also very useful in hair transplant procedures. Surgeons can move the camera simply by moving their eyes.[11]

The National Institute of Health (NIH) developed an AiCure App, which supervises medication use by patients via smart-phone webcam access and thus minimise non-adherence rates.[12] Fitbit, Apple, and other health trackers can monitor heart rate, activity levels, sleep levels, and some have even launched ECG tracings as a new feature. Apart from existing inventions, there are certain advancements in various stages of development. IBM's Watson Health, for example, will be able to determine symptoms of heart disease and cancer. "Molly", a virtual nurse is being developed to provide follow-up care to patients who've been discharged, allowing doctors to focus on more pressing cases.[8]

3. Clinical Application of AI in Dentistry

3.1. Radiology

AI is steadily entering the field of radiology, with a focus on diagnostic records of virtual IOPAs/RVGs, 3-D scans, and cone-beam computed tomography. It can be used in conjunction with imaging systems such as MRI and CBCT to detect minute deviations from normalcy that would otherwise go unnoticed by the human eye. This can also be used to precisely locate landmarks on radiographs for cephalometric diagnosis.[7] Convolutional Neural Networks (CNNs) have shown potential in detecting and identifying anatomical structures. Some have been trained, for example, to identify and label teeth from periapical radiographs. They have also been used to detect and diagnose dental caries. They have an increased potential for enhancing the sensitivity of dental caries diagnosis, which, combined with their speed, makes them one of the most effective tool in this domain.[13–16] Machine Learning (ML) algorithms can detect an abnormal or normal lymph node in a head and neck image if interpreted by a trained Radiologist who has analysed thousands of such images labelled as normal or abnormal.[17]

3.2. Orthodontics

Artificial intelligence is becoming increasingly popular in the field of orthodontics. Artificial neural networks (ANN), convolutional neural networks (CNN), support vector machines, and regression algorithms are the most frequently used type of algorithms in orthodontics.[18] ANNs have enormous ability to aid in clinical decision-making. In patients with malocclusion, an ANN was used to help determine the need for tooth extraction prior to orthodontic therapy.[19,20] Auconi et al. created an ANN-based system to predict treatment outcomes in class II and III patients. The analysis could predict the co-occurrence of auxological anomalies during individual craniofacial growth and possibly localize reactive sites for a therapeutic approach to malocclusion.[21,22] The result suggests, deep learning neural networks may be the best for detecting TMJ osteoarthritis. Furthermore, ANN may aid in the determination of growth and development periods. The most common uses of neural networks in orthodontics are in diagnosis and treatment planning, automated anatomic analyses, growth and development

assessment, and treatment outcome evaluation. It appears that artificial intelligence in orthodontics will be widely used, and its application will undoubtedly be expanded.[18]

3.3. Periodontics

Periodontitis is a widespread disease that affects billions of people worldwide, causing tooth mobility and, in severe cases, tooth loss, if left untreated. To avoid this, early disease detection and effective treatment must be implemented. Periodontal probing has limited accuracy due to individual examiner's assessment. Dental radiographs are a common additional examination, whose evaluation also depends on the examiner's experience. Some authors have used neural networks to reduce diagnostic error. CNN had higher accuracy (83%) and reliability (80%) than dentists in detecting periodontal bone loss. Neural networks may be useful tools for assessing radiographic bone loss and obtaining image-based periodontal diagnosis.[23] ANNs can also be used to accurately diagnose aggressive (AgP) or chronic periodontitis (CP) using relatively simple and easily obtained parameters such as leukocyte counts in peripheral blood.[24] Using AI, the accuracy of periodontally compromised teeth (PCT) diagnosis proved to be 76.7–81.0%, while the accuracy of predicting the need for extraction was 73.4–82.8%.[25] However, apart from all of these applications, the most common and simple to understand is our dental chair, which a dentist uses all day for his patients. AI has transformed the dental chair from a traditional hydraulic chair to an electrical and fully automatic dental chair controlled by sensors. The most recent and significant advancement is the voice command operated dental chair, which eliminates the need for the dentist to exert physical effort. That day is not far off when a dental chair would calculate a patient's weight, vital signs, and anxiety while the patient sits in the chair for treatment.[17]

3.4. Endodontics

Endodontics is becoming more reliant on artificial intelligence. It can be used to detect periapical lesions and root fractures, evaluate the anatomy of the root canal system, predict the viability of dental pulp stem cells, ascertain working length measurements, and predict the success of retreatment procedures.[26] On radiographs, artificial neural networks could be used as a decision-making system to spot the minor apical foramen.[27] Furthermore, CAD/ CAM-based systems are used in dentistry to achieve highly precise finished dental restorations.[28]

3.5. Dental surgery

Neural networks in dental surgery could be widely used in a variety of areas, beginning with orthognathic surgeries, bone changes, or post-extraction complications, and concluding with implantology treatment. Implantology, in particular, is a rapidly developing field, and the use of neural networks in everyday practice may be very beneficial due to the need for high precision and meticulous planning. Neural networks may also help predict and avoid some complications that may occur during surgical treatment.[18] Introduction of robotic surgery, is one of the most significant applications of AI in the field of oral and maxillofacial surgery. Simulating human body motion and intelligence is a critical challenge in robotics.[29] However, artificial intelligence (AI) has revolutionised the field of surgery, and there are now many robotic surgeons that perform semi-automated surgical tasks enhancing efficiency under the supervision of an expert surgeon. Finally, one of the most groundbreaking applications of AI is seen in the field of "bioprinting," in which living tissue and even organs can be constructed in successive thin layers of cells which might be used in the future to reconstruct oral hard and soft tissues lost due to pathological or accidental reasons.[30]

3.6. Prosthodontics

A dentist must consider several factors in order to provide a perfect prosthesis to the patient, including anthropological calculations, facial measurements, aesthetics, and patient preferences. Another discovery of Artificial Intelligence in dentistry is the use of computer-aided technology for precise fitting of prostheses. Inlays, onlays, crowns, and bridges are also designed using AI-based systems. This system has transformed the traditional method of casting the prosthesis, reducing time and errors.[31]

3.7. Oral pathology

Early detection and diagnosis of oral lesions is critical in dental practice because it improves prognosis significantly. Since some oral lesions can be precancerous or cancerous, it is critical to make an accurate diagnosis and treat the patient appropriately. CNN has proven to be a valuable tool in the diagnosis of head and neck cancer lesions. It has a lot of potential for detecting tumours in tissue samples or on radiographs.[32] The Artificial Neural Network (ANN) may also be useful in identifying and grading patients at high risk of oral cancer or pre-cancer, as well as in planning a treatment regimen.[17]

3.8. Public health dentistry

Artificial intelligence has been implemented with demonstrable success in academic research and inference tasks throughout the wider economic system, but much less so in core public health functions, specifically protecting and promoting population health. AI has the potential to improve the efficiency and effectiveness of processes across an expanded public health system.

3.8.1. Health protection

The potential use of artificial intelligence in health protection is to analyse data patterns for near-real-time surveillance and disease detection. It can, for example, be used to screen and identify suspected changed mucosa undergoing premalignant and malignant changes, as well as to diagnose and treat oral cavity lesions.[11] It may also offer emergency tele-assistance in dental emergencies where the dental health care expert cannot be reached.[7]

3.8.2. Health promotion

AI offers targeted and personalised health advice based on risk profile and behavioural pattern. For example, informing the dental healthcare provider of any relevant medical history, could accurately predict a genetic predilection for oral diseases in a large population.[11]

3.8.3. Health education

The field of intelligent tutoring systems has come a long way since its inception in the 1980s. With the recent inclusion of artificial intelligence in intelligent tutoring systems such as the Unified Medical Language System (UMLS), there has been a significant improvement in the quality of feedback provided to students by the pre-clinical virtual patient. The interactive interphase allows students to evaluate and compare their work to the ideal, resulting in high-quality training environments. A number of studies on the efficacy of these systems have found that students achieve a competency-based skill level faster, than with traditional simulator units.[33,34]

3.8.4. Public health surveillance

Over the past decade there have been significant improvements in outbreak detection methods, including (but not limited to) local and temporary data analysis, integration of multiple data streams, and improved detection performance measurement metrics. Current diagnostic programmes rely heavily on large data sets derived from non-traditional sources, such as internet search queries and user-generated web content, electronic health records, and continuous data streams derived from sensory networks, mobile phones, and other location-aware devices. This shift in public data analysis will necessitate a consistent shift in methods used in functional diagnostic systems, such as techniques from artificial intelligence, machine learning, and data mining, to determine large amounts of data, appropriate patterns, and aid in public health decision making. Experts will rely heavily on tools and systems that use advanced statistical methods to distinguish associated ineffective patterns, scalable algorithms to process large amounts of complex, high-dimensional data, and machine learning methods to improve system performance based on user feedback.[11]

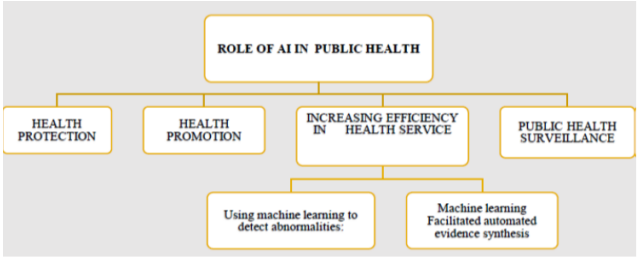

Fig. 1: Role of Artificial Intelligence in Public Health by Tariq S et al. 2021

4. AI and Dental Clinic Management

The roles and significance of AI in the public oral health upgrade are best demonstrated in dental clinic management or general operations. One of these aspects is scheduling patient appointments, and newly appointed assistants can be easily trained to perform such tasks more efficiently and productively. Another advanced aspect of AI in scheduling appointments is the possibility to track and optimize patient appointments so that it allows to "proactively schedule unfinished treatment and launch new-patient marketing campaigns based on profit maximization algorithms". Such optimization is accomplished through the use of machine-learning programmes that can interact with dental practice software.[35]

Deep learning techniques, on the other hand, enable searching patient records for the most profitable patient treatment. In this sense, assistants spend less time dealing with prescriptions after surgery and can act more quickly before the appointment if there is an emergency with a patient to be recognized. Furthermore, and to the greater benefit of patients, AI can assist the dental health care professional with any relevant medical history or allergies that the patient may have. Patients who are on tobacco or smoking cessation programs, for example, can utilize AI to set up necessary reminders.[4] In contrast to other (traditional) methods of work in dental clinics, AI software enables us to create a comprehensive virtual database for each patient that is both simple to use and accessible. For example, voice recognition and interactive interphases allow the software to assist the dentist in performing various tasks with ease.[36]

5. AI in Economic Perspective of Dental Care

Another area of dentistry where AI has proven to be extremely beneficial is the financial aspect of dental care. When dealing with the same documentation, dental AI makes the dental process more transparent for both providers and consumers. In other words, dentists who use AI in their clinical workflow will be able to determine whether there is proper, evidence-based documentation and whether it is in compliance with the insurer's policies.

For example, if it is necessary to photograph a broken cusp that is not visible on a radiograph, AI systems can determine the need for a photograph. Misinterpretations of clinical guidelines are reduced as a result, and care providers become more familiar with the objective measures used by payers. Recent research suggests that AI-enhanced claims review will ultimately lower costs since every time an appeal is filed or a claim is resubmitted, it increases costs to both parties. If used routinely, the AI system ensures the validity and confidence of patients in their prospective dental benefits and treatment plans. As a result, improved efficiency in reviewing claims will speed up reimbursement and reduce administrative costs for payers. This will reflect the slower growth of premiums for patients and employers. Another significant financial benefit of the AI system in dental clinics is instant predetermination, as many dental payers now offer predeterminations or pre-estimates in costly procedures. AI adoption has already commenced for internal claims review and in provider offices. Finally, the AI paradigm reduces financial uncertainty for patients while also assisting general dentistry in resolving delays that can discourage medically necessary treatments.[4]

6. Pros and Cons of AI in Dentistry[17]

6.1. Pros

1. Execute tasks instantly.
2. Logical and feasible decisions which results in an accurate diagnosis.
3. Standardization of procedures is possible.

6.2. Cons

1. Mechanism/system complexity.
2. Expensive setup.
3. Appropriate training is necessary.
4. The outcomes of AI in dentistry are not readily applicable
5. Data is frequently used both for training and testing, leading to "data snooping bias"
6. The transparency of AI algorithms and data is a significant issue.

7. Conclusion

To summarize AI is not a myth, but rather our future in dentistry. It has the potential to transform oral health care by assisting in addressing the flaws that have been harshly criticized in traditional dental care. In several dental task domains, it has improved clinical diagnosis and decision-making performance. But how this performance will translate into impact on the landscape of dental practice, including disease detection and treatment, will depend on how quickly AI applications co-evolve with a healthcare system that is under immense financial strain while accommodating rapid advances in molecular and genomic science.

The use of AI should be viewed as a supplement to dentists and specialists. To ensure that humans retain the ability to direct treatment and make informed decisions in dentistry, AI must be incorporated in a safe and controlled manner. The path to successful AI integration in dentistry will require dental and continuing education training, a challenge that most institutions are not currently prepared for. This review demonstrates that artificial intelligence has advanced rapidly in recent years, and it may soon become a normal tool in modern dentistry. The benefits of this include increased efficiency, accuracy and precision, improved monitoring, and time saving. More research on the use of neural networks in dentistry is required before they can be utilized in everyday practice to help dentists. However, there is some debate about the superiority of incorporating AI into practice; it does not, in any way, replace the role of a dentist. Although AI can assist in a variety of ways, the final decision must be made by a dentist because dentistry is a multidisciplinary approach.

8. Conflict of Interest

The authors declare that they have no conflict of interest.

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None.

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