CURRENT & FUTURE TRENDS OF AI IN DENTAL RADIOLOGY

Abstract

Artificial intelligence (AI) is described as "a branch of science and engineering focused on computationally comprehending what is commonly referred to as intelligent behavior and producing artifacts that demonstrate such behaviour". Artificial intelligence was once considered a distant and fantastical dream for the future, but it has progressively transformed into a tangible reality across various industries, including the dental and medical sectors. Notably, artificial intelligence has found recent applications in the domain of dentistry, particularly in the field of oral and maxillofacial (OMF) radiology, where it is employed to analyse radiographic images. This chapter intends to highlight the current and future trends of AI in Dental Radiology.

Keywords: Dental Radiology, Artificial Intelligence (AI).

Authors

Dr. Syed Shahbaz
Reader
Department of Oral Medicine & Radiology
Al Badar Dental College & Hospital
Kotnoor, Kalaburagi, Karnataka, India.
drsshahbaz@gmail.com

I. INTRODUCTION

Since the inception of scientific inquiry, extensive research has been conducted to unravel the intricate nature of the human brain. The human brain operates through interconnected neurons that facilitate the transmission of signals throughout the entire body. Scientists have dedicated considerable efforts to crafting and refining models that replicate the functions of the human brain, but this endeavor has remained an enigmatic challenge. Despite the formidable nature of this task, scientists have persevered with unwavering determination over the course of many years in pursuit of advancing the field of artificial intelligence (AI) [1].

Artificial intelligence (AI) is described as "a branch of science and engineering focused on computationally comprehending what is commonly referred to as intelligent behavior and producing artifacts that demonstrate such behavior" [2,3]. To provide a clearer understanding, Artificial Intelligence (AI) is recognized as computer systems capable of executing tasks typically demanding human intelligence, such as mathematical calculations, weather forecasting, speech recognition, decision-making, medical diagnosis, and more [4].

Artificial Intelligence (AI) is fundamentally categorized into Machine Learning (ML) and Deep Learning, which is closely associated with convolutional neural networks (CNN). Machine learning deals with "the problem of constructing computer programs that can improve themselves through experience" [4]. Deep learning, on the other hand, falls within the realm of machine learning and focuses on algorithms inspired by the structure and function of the brain. In recent years, there has been remarkable progress in the fields of medicine and dentistry. AI technologies, particularly those rooted in deep learning, have found significant utility in the realm of image recognition. Specifically, AI algorithms excel in autonomously recognizing intricate image data and providing quantitative assessments of imaging features [2, 3, 4].

Artificial intelligence was once considered a distant and fantastical dream for the future, but it has progressively transformed into a tangible reality across various industries, including the dental and medical sectors. Notably, artificial intelligence has found recent applications in the domain of dentistry, particularly in the field of oral and maxillofacial (OMF) radiology, where it is employed to analyze radiographic images.

II. CURRENT TRENDS

Advancements in both radiology and AI have brought greater attention to the role of the radiologist as a diagnostician, which primarily involves two processes: the assessment of radiographic images followed by their interpretation. Both processes entail the ability to visually discern an image and the perceptual skill to apply object detection to distinguish normal from abnormal findings. This task can be challenging, as human perception of stimuli may occasionally result in oversight and errors. Negligence on the part of radiologists can lead to missed or delayed detections, potentially resulting in adverse health outcomes. In the era of automated imaging repositories and electronic health record systems, the integration of AI into radiology is posited to not only enhance accuracy but also streamline and reduce the cost of image processing [1].

The artificial neural network (ANN) stands out as the predominant and highly effective method employed in the majority of current AI applications within the field of radiology. ANNs have risen to become the most widely adopted AI framework in contemporary medicine. These computer systems emulate the functioning of the human brain, comprising networks of tightly interconnected computational units that emulate neurons. They perform simultaneous data processing tasks and incorporate intricate weighted connections.

The device's information database encodes the weighting of each relationship, and each 'neuron' employs this weighting, guided by statistical logic, to determine whether to activate other 'neurons' within the network. ANNs offer a host of advantages that have contributed to their dominance in the field of AI within radiology. ANNs can be trained using supervised learning, involving the comparison of predicted outcomes. Alternatively, they can learn through unsupervised learning, where the weighting of their interactions is adjusted through interpretations and correlations with input data. With unsupervised learning, ANNs progress on a case-by-case basis, steadily enhancing their diagnostic accuracy over time, independent of expert feedback. This capability also enables ANNs to leverage their experience with simpler cases to tackle more complex ones.

In the realm of oral radiology, specific algorithms can be developed to assist in the identification and suggestion of suitable treatment options. Artificial intelligence is steadily gaining ground in dental radiology, with a focus on leveraging patient data from digital scans and radiographs. This expanded dataset allows for enhanced utilization of AI to expedite diagnosis and improve healthcare management. The cornerstone of effective clinical practice lies in thorough evaluation. In this context, adequately trained neural networks can prove beneficial for diagnosis, particularly in cases with multifactorial causation [1].

III. APPLICATION OF ARTIFICIAL INTELLIGENCE IN ORAL MEDICINE AND RADIOLOGY

AI, or Artificial Intelligence, presents an extremely valuable approach for diagnosing diseases and managing oral lesions. It can effectively categorize and screen altered oral mucosa for malignant and premalignant changes using advanced technology. Radiology serves as the gateway for AI's integration into medicine, as digitally encoded diagnostic images can be easily translated into computer-readable language. Consequently, diagnostic images are regarded as a primary source of data for the creation of AI algorithms that automate disease risk prediction, pathology detection, and disease diagnosis [5].

Artificial Intelligence in Patient Management: AI-driven virtual dental assistants excel in performing a variety of dentistry-related tasks with exceptional precision, reduced reliance on human resources, and minimal errors compared to human counterparts. Their applications extend from handling administrative tasks such as paperwork, insurance processes, and appointment scheduling to providing assistance in treatment planning and clinical diagnosis. Dentists receive alerts regarding the patient's medical history and lifestyle habits, such as smoking and alcohol consumption. In cases of dental emergencies and when practitioners are unavailable, patients have the option to access tele-assistance. This virtual database, thus provided for the patient, significantly enhances treatment opportunities [6].

AI in Automated Analysis: In the process of building the training set, a clinical expert meticulously analyzes and compiles a specific dataset from the extensive pool of available radiographs. The annotation of this training data is carried out manually by either an oral radiologist or an experienced clinician. Subsequently, the AI software undergoes training using these datasets to construct an adapting dataset. The accuracy of this adapting dataset is then assessed using a testing dataset, which consists of a fresh set of radiographs that have not been previously evaluated. This illustrates how AI contributes to the automated analysis of dental radiographs [1].

AI in Anatomical Landmarks Detection: Convolutional neural networks (CNNs) enable precise edge detection, and a combination of edge-based, region-based, and knowledge-based algorithms is employed to identify cephalometric landmarks. This technology proves especially valuable in locating landmarks that possess low contrast, overlap with other structures, or exhibit poor image quality, challenges that can be difficult for the human eye to discern. CNNs enhance anatomical landmark detection by facilitating pixel-by-pixel analysis and utilizing knowledge-based algorithms. Consequently, automated analysis of dental radiographs ensures the accurate localization of landmarks and can also be applied to CT and MRI scans for the identification of abnormalities that might otherwise go unnoticed in the images [1].

AI in Dental Caries and Periapical Pathologies Detection: AI plays a pivotal role in the identification of interproximal caries through the analysis of a series of bitewing radiographs. For the diagnosis of dental caries in bitewing, periapical, and panoramic radiographs, a pre-trained deep learning network can be effectively employed. AI significantly contributes to the detection of periapical pathologies, including periapical cysts, granulomas, and abscesses, which may occasionally elude a clinician's observation. AI excels in accurately delineating the precise boundaries of these lesions, thereby enhancing detection accuracy. Looking ahead, these systems hold the potential to facilitate early detection of peri-implantitis, leading to timely interventions [1].

Artificial Intelligence for Early Oral Cancer Detection: Timely detection of oral cancer is pivotal for effective treatment. In oral and maxillofacial radiology (OMR), it is essential to establish a routine that involves a comprehensive examination of the entire oral cavity to identify alterations indicative of early-stage oral lesions. Research indicates that both professionals and students may lack the confidence necessary for accurate diagnoses. This gap in expertise has presented an opportunity to develop an auxiliary diagnostic device that leverages AI to identify early changes in the oral mucosa. AI possesses the capability to identify alterations that may elude the untrained human eye, thereby facilitating the early detection of changes within the oral cavity [6].

Artificial Intelligence in the Diagnosis of Temporomandibular Joint Disorders: The diagnosis of temporomandibular joint (TMJ) disorders typically involves the collection of medical history, clinical examination, and radiographic evaluation. Clinically, these TMJ disorders manifest distinct signs, including restricted lower jaw movement, accompanied by pain, crepitus, and local paraspinal tenderness in the affected joint. The confirmation of these disorders often relies on radiographic assessments that reveal structural changes in the bone [6].

Artificial Intelligence in the Detection of Cysts and Tumors: Typically, jawbone tumors and cysts remain asymptomatic unless they grow significantly, leading to expansion that may result in pathologic fractures or compression of nerve canals. In rare instances, malignant transformations from benign jaw lesions have been documented. Late-stage surgical interventions, which often require radical approaches such as reconstruction, free flaps, and bone grafts, can profoundly impact a patient's life by causing facial deformities and subsequent emotional and social challenges. Early diagnosis stands as the sole means to ensure a healthy quality of life. In conjunction with AI technology, numerous studies are conducted on the early detection of cysts and tumors within the maxillofacial region [6].

Artificial Intelligence in the Diagnosis of Fractures: Fractures represent a prevalent injury type observed in the oral and maxillofacial regions, with the mandible being the most frequently affected site. These fractures typically result from incidents such as assaults, vehicle accidents, falls, or altercations, among others. Radiologists predominantly employ CBCT and panoramic radiography for the diagnosis of mandibular fractures. Notably, artificial intelligence and deep learning have been advancing rapidly in this domain, demonstrating promising capabilities in the detection of fractures in recent years [6].

Artificial Intelligence in Forensic Odontology: Forensic odontology encompasses the assessment, investigation, handling, and presentation of dental evidence in support of civil and criminal legal proceedings, all in the pursuit of justice. In cases where dental remains serve as the sole available evidence, this field holds the capacity to deliver justice. Artificial intelligence technology has emerged as a significant breakthrough in providing dependable information for decision-making within the realm of forensic sciences [6].

IV. ADVANTAGES OF ARTIFICIAL INTELLIGENCE. [6]

1. **Managing Abundant Data:** The treatment cycle for each patient generates a substantial amount of data, encompassing activities such as appointment scheduling, patient medical and behavioral history, dental impressions, and routine IOPA X-rays. Moreover, data generation is not confined solely to activities within the dental clinic but extends to external factors like marketing a dental practice and monitoring patient reviews on social media platforms. When confronted with a vast and intricate dataset, there arises ample opportunity for AI to undertake various tasks. These datasets can be employed to develop AI algorithms in diverse formats, including natural text, tabulated data, digital images/videos, and audio. AI not only excels in data analytics but also can execute routine tasks and functions, thereby aiding dentists in alleviating their overall workload.

2. **Diagnostic Precision:** Research in the realm of AI applied to Radiology has demonstrated that appropriately trained AI models can significantly enhance the interpretation of X-rays, effectively identifying conditions that were often misinterpreted or overlooked by human observers. The enhanced diagnostic accuracy achieved through AI not only saves time and resources but also contributes to improved dental health outcomes for patients.

3. **Efficiency-Boosting Tool:** The integration of AI technology into dentistry offers the potential to streamline and enhance various administrative tasks, making them more time-efficient and cost-effective. Utilizing AI technology enables professionals to allocate

more time to focus on crucial matters, ultimately improving job performance. An example of AI's practical application is virtual consultations, which not only save patients time but also benefit clinicians by providing advanced knowledge of the next steps in a patient's treatment plan prior to their visit.

V. DISADVANTAGES OF ARTIFICIAL INTELLIGENCE [6]

1. **Distributional Shift:** When there is a change in the environment or conditions, data discrepancies can occur, resulting in inaccurate predictions. For instance, alterations in disease patterns can create disparities between the testing and training datasets. Insensitivity to Consequences: Despite its capabilities, AI does not factor in the consideration of positive outcomes or false negatives.

2. **Black Box Decision-Making:** AI-driven prognostication often remains opaque and impervious to interpretation or scrutiny. For instance, issues within the training dataset can result in inaccurate X-ray analyses that the AI system cannot rectify or account for.

3. **Automation Complacency:** Clinicians may develop unwavering trust in AI tools, assuming that every prognosis generated is accurate, and they may neglect to explore alternative options or conduct cross-checks.

4. **Preservation of Outdated Practices:** AI lacks the capacity to adapt during changes or developments in enforced medical policies, as it relies on historical data within its trained system and cannot acclimatize accordingly.

5. **Self-Fulfilling Prediction:** An AI model is trained with the specific aim of achieving improved outcomes in the identification of a particular illness.

6. **Reward Hacking:** AI models, aiming to attain rewards tied to proxy objectives, have the capacity to identify and exploit loopholes and hacks to obtain unearned rewards without truly fulfilling the primary objectives.

7. **Unsafe Exploration:** An AI system may begin to acquire new strategies for achieving the desired end result in an unsafe manner.

VI. FUTURE TRENDS

Future of the AI in dentistry mainly depends on addressing the key shortcomings in its use such as complexity involved in the system or mechanism, expensive setup, lack of proper training in the models, and data snooping bias. Further, the outcomes of the models are not sometimes readily applicable in the dentistry. There are several foremost challenges which are to be addressed for successful implementation of AI in health care. The clinical data sharing and management are very critical in successful implementation of AI systems. The AI systems and algorithms need personal data of the patients for validation and improvement of the system and often they share these data among different institutions also across the national boundaries. Hence, the patient data sharing and management have to be strictly followed as per laid down guidelines to ensure that the privacy of the individual is not affected. Further, the systems must require to adapt to protect the patient confidentiality and privacy in order to integrate AI and clinical operations. The personal data have to be anonymized before any sharing and broader distribution. [7,8]

Even with these precautions and checks in place, the health-care community is still sceptical about the protection of the data in sharing. Hence, this challenge is to be addressed properly with transparency on the precautions taken to ensure successful implementation of AI in health care. Further, the AI systems also have safety issues and hence there should be mechanisms in place in order to control the quality of the algorithms and systems used in AI. Another challenge in implementation of AI is ambiguous accountability in its use. Many times, there is no clarity on the accountability associated with any unintentional consequences faced by patients as a result of any adverse event in the AI system and the algorithm usage. Substitution of humans with autonomous agents gives scope to various questions regarding the legal and ethical order, and these issues pose challenge to the current legal system. Transparency of the algorithms is another substantial challenge faced by AI in its implementation in health care and dentistry. The predictions heavily rely on the accurate annotations and labelling of the datasets used in the training of the algorithm. Hence, any poorly labelled data will cause distracted results. Further, the clinic labelled datasets may itself be of inconsistent quality and thereby having significant effect on the efficacy of the AI systems. [1]

Health-care authorities also should fully understand the decisions and predictions of the AI system in order to defend the decisions. Hence, interpretability of these AI systems and consequences has always been a challenge in the implementation of the technology. Hence, major advances are also required to ensure transparency and increase interpretability of the results and outcomes. [1]

VII. CONCLUSION

Artificial intelligence, a field that has witnessed widespread application across various industries in recent years, garners significant attention from numerous researchers. Dentistry is no exception to this trend, and the potential applications of artificial intelligence hold great promise, particularly in the realm of oral and maxillofacial (OMF) radiology. Recent studies in the domain of artificial intelligence within OMF radiology have predominantly leveraged convolutional neural networks, capable of performing tasks such as image classification, detection, segmentation, registration, generation, and refinement. AI systems in this field have been developed for purposes encompassing radiographic diagnosis, image analysis, forensic dentistry, and the enhancement of image quality [9].

Substantial volumes of data are indispensable to achieve favorable outcomes, and the active participation of OMF radiologists remains crucial for generating accurate and consistent datasets, a task that consumes a considerable amount of time. To enable the widespread adoption of artificial intelligence in clinical practice in the forthcoming years, several challenges must be addressed. These include the creation of extensive, meticulously labeled open datasets, comprehension of artificial intelligence judgment criteria, and the mitigation of DICOM hacking threats involving artificial intelligence. Should solutions to these challenges emerge in tandem with artificial intelligence advancements, we can anticipate its further evolution in the future. Artificial intelligence is poised to assume a pivotal role in the development of automated diagnostic systems, the formulation of treatment plans, and the production of treatment tools [9].

Oral and maxillofacial (OMF) radiologists, possessing a deep comprehension of radiographic image features, will assume a highly significant role in advancing artificial intelligence applications within this domain. While AI cannot supplant the role of dentists or oral radiologists, the precise and efficient analysis of radiographic images by artificial neural networks presents intriguing diagnostic prospects for the future. It is expected to become an integral component of the field of oral radiology.

REFERENCES

[1] Lingam AS, Koppolu P, Akhtar F, Afroz MM, Tabassum N, Arshad M, et al. Future trends of artificial intelligence in dentistry. J Nat Sci Med 2022; 5:221-4
[2] Sourav Bose, Jaideep Sur, Fatima Khan, DeeplaxmiDewangan, Dmitry Tuzoff, MdTafique Raza, Ayesha Roul, EktaSawriya. The Scope of Artificial Intelligence in Oral Radiology- A review. Int J Med Health Sci. Oct 2020;9(4):67-72
[3] Encyclopedia of Artificial Intelligence | Guide books. [cited 2020Apr1]. Available from: https://dl.acm.org/doi/book/10.5555/531550
[4] Artificial intelligence [Internet]. Oxford Reference. [cited 2020Apr1]. Available from:https://www.oxfordreference.com/view/10.1093/oi/authority.20110803095426960
[5] Hung K, Yeung AWK, Tanaka R, Bornstein MM. Current Applications, Opportunities, and Limitations of AI for 3D Imaging in Dental Research and Practice.Int J Environ Res Public Health[Internet]. 2020 Jun 1;17(12):4424.
[6] Sindhu P, Ramnarayan BK, Preeti P, Mahesh DR, Darshana SN, Chaya MD. Current and Future Trends of Artificial Intelligence in Oral Medicine and Radiology- A Review. Eur. Chem. Bull. 2023;12(Si6):6066-6081
[7] Lim K, Moles DR, Downer MC, Speight PM. Opportunistic screening for oral cancer and pre-cancer in general dental practice: Results of a demonstration study. Br Dent J 2003; 194:497-502.
[8] Yaji A, Prasad S, Pai A. Artificial intelligence in dento-maxillofacial radiology. ActaSci Dent Sci2019; 3:116-21.
[9] Heo M-S, Kim J-E, Hwang J-J, Han S-S, Kim J-S, Yi W-J, et al. Artificial intelligence in oral and maxillofacial radiology: what is currently possible? Dentomaxillofac Radiol 2020; 50: 20200375.