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Artificial Intelligence in Oral Medicine and Radiology- An Overview

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ABSTRACT:

Dentistry has developed and progressed in many aspects over the past few years. New technological advances have paved the way for the revolutionization of diagnosis and conventional dental treatment. Artificial intelligence is a highly evolved system capable of mimicking functioning of the human brain. It is defined as the field of science and engineering related to the computational understanding of intelligent behaviour and production of the artifacts that exhibit such behaviour. Introducing artificial intelligence in the field of dentistry could reduce time consumption, cost and human errors. AI application in dentistry include diagnosis and its differential diagnosis, imaging and management of head and neck diseases and in dental emergencies. This results in increased standard of diagnosis and management of oral and maxillofacial disorders. This article aims to provide an outlook about various techniques and applications of artificial intelligence in the field of oral medicine and radiology.

1. Introduction:

Artificial intelligence is a highly developed branch of computer science that mimic the functioning of the human brain. In 1956, John McCarthy first used the term AI (1). AI is a general term referring to task performance with the help of machine and technology. According to 'Barr and Feigenbaum', it is the part of computer science associated with designing a computer system that exhibits characteristics of intelligence in human behaviour-understanding language, learning, reasoning, problem solving, and many more. Subcategories of AI include machine learning, deep learning, fuzzy logic, cognitive computing, robotics, natural language processing and expert systems. AI is transforming as an emerging advanced technology in the field of dentistry (2).

AI has been mainly used to track and diagnose diseases, work decision support systems, indicate prognosis and predict its therapeutic response, improvement of care by creating it more efficient and affordable. AI can be used in oral radiology to ease clinical practice by marking cephalometric tracings using software which reproduce it automatically, effectively, and quickly optimising the time of professionals. Radiographic diagnosis such as the early detection of caries lesions, detection and classification of dental implants from radiographic images using AI provide diagnostic accuracy that can establish better prognosis (3).

Development of radiographic interpretation systems encounters many challenges. Perhaps most basic is the identification of normal anatomic structures. A further benefit of AI is removal of human bias while interpreting images [4].

2. **Techniques of AI applied in oral medicine and radiology:**

a) Artificial neural networks (ANN)
b) Clinical Decision Support System (CDSS)
c) Principal Component Analysis (PCA)
d) Data Mining technique
e) Fuzzy Logic
f) Belief Merging
g) Genetic Algorithms (GA)
h) Probabilistic and General Regression Neural Network
i) Dynamic Bayesian Networks
j) Deep Learning (DL)
k) Machine Learning (ML)

Artificial neural networks (ANN):

ANN is mainly used for assessing the degree of aggressive activity of cancer and to predict the course of the disease and prognosis providing prospective suggestions to treatment modalities. It has similar structure and function as that of the brain. It is composed of perceptron's that functionally simulate the neurons. Well-grounded vehicle for exploring the predictive potential of biomarkers for oral cancer [5].

Clinical Decision Support System (CDSS):

CDSS are interactive computer programs designed for decision-making tasks. Clinical knowledge is used to investigate patient data and make decisions regarding diagnosis, prevention, and treatment of orofacial disorders. It can be used as standalone system and also combined with other tools like electronic dental record, order entry system, or radiology system for multitasking. It warns the dentist regarding drug allergies, remind screening for oral cancer in a smoker, for periodontal disease in a patient with diabetes. This system provides prognoses including the prediction of lesion's susceptibility to malignancy. It is used for the early detection and diagnosis of oral cancer [5].

Principal Component Analysis (PCA):

Principal component analysis (PCA) technique is one of the most unruled dimensionality reduction techniques. The goal of the technique is to find a space, which represents the direction of the maximum variance of the given data. Preprocessing steps in machine learning application include dimension reduction which transforms the features into a lower dimension space. Application of PCA include image compression, biometrics and visualisation of high-dimensional datasets [6].

Data Mining technique:

It is an arithmetic process of finding patterns in large data sets. It extracts information from a data set and converts it into an accessible structure for further use. It is the analysis step of the "knowledge discovery in databases" process involving detection of anomaly, clustering, association rule mining, classification, regression, and summarization. It is a novel method for diagnosis and prognosis of oral cancer [7].

Fuzzy logic:

Fuzzy logic system (FLS) is a nonlinear mapping of an input data set to a scalar output data. Four main parts are fuzzifier, rules, inference engine, and defuzzifier. It can be used for prediction, detection and diagnosis of oral cancer risk assessment. It has high diagnostic accuracy [8].

Belief merging:

Belief merging considers plan for combining symbolic information, expressed in propositional logic, coming from different sources. Each source is coded as a set of propositional formula and known as a belief base. Used for diagnosing oral cancer [9]

Probabilistic and General Regression Neural Network:

(PNN/GRNN) models are helpful to diagnose patients with malignancy. Type of malignancy can be determined based on information regarding demography, clinical signs and symptoms, medical and personal history, and gross examination. It is used to anticipate the stage and extent of oral cancer based on symptoms and also predicts the survivability of patients after treatment and follow-ups [10]

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Deep learning:

DLS can learn to extract relevant image features and to perform image classification without manual input of the image features. Image data are put in the top layer, learning of correct classification occurs by transmission of information through various layers, with proposed classification in the final layer. It will reduce the workload of radiologists and physicians in molecular imaging for early diagnosis of cancer. Used to evaluate cervical lymph node metastases in oral cancer (11)

Machine learning:

It enables computers to learn from historical data, gather insights and make predictions about new data using the information learned. It has high degrees of accuracy and precision. Statistics mainly focus on inference and describes how a system of components relate to one another. Machine learning focuses on making predictions about an unknown variable based on past experiences using large sets of patient data (12)

Artificial intelligence in the IMRT planning process:

Dose prediction Prior knowledge of the volumetric dose of a prospective patient undergoing radiotherapy would have a substantial impact on clinical workflows involved in IMRT treatment planning since it would provide dosimetric expectations which could be used to help identify outliers and planning cutoff criteria (13). Three main types of volumetric dose prediction techniques are: Atlas-based, fully connected neural networks, Convolutional neural networks

Dynamic Bayesian Networks:

The dynamic Bayesian networks take into consideration time-series gene expression data collected at the follow up study of patients that had or had not suffered a disease relapse. Based on that knowledge, to infer the corresponding dynamic Bayesian networks and subsequently conjecture about the causal relationships among genes within the same time-slice and between consecutive time-slices. It can assess the prognosis of patients regarding oral cancer recurrence (14).

3. Applications in oral medicine and radiology:

Detection of dental caries:

To identify interproximal caries using a series of bitewing radiographs. For the diagnosis of dental caries in bitewing, periapical and panoramic radiographs, deep learning network which is pre trained can be used (15).

Detection of oral cancer:

It is used for early diagnosis of oral carcinomas, detection of cervical lymph node metastasis which may result in improving the prognosis of head and neck cancer, helps in selecting better treatment options reducing unnecessary treatment protocols (15)

Detection of anatomical landmarks:

Convolutional neural network (CNN) allows exact edge recognition and edge-based, region-based, and knowledge-based algorithms to find cephalometric landmarks. It can help to locate landmarks which are of low contrast, overlapping or of bad quality thus making it difficult to detect for a naked human eye. Enables the exact confinement of landmarks and can also be utilized with CT and MRI to recognize variations that may go unnoticed (15)

Detection of periapical pathologies:

A clinician may occasionally miss periapical pathologies such as periapical cysts, granulomas, and abscesses, but AI can assist in their diagnosis. It can provide proper detection by precisely locating boundaries of the lesion (16)

Detection of bone loss:

Radiologists will be helped by ANN to lessen cognitive bias and diagnostic efforts and further improve the periodontal pathology diagnosis accuracy. In the radiographic identification of periodontal bone loss, neural networks performed better in terms of diagnostic performance than individual physicians (16)

Temporomandibular Joint Disorders:

Usually, they are diagnosed by eliciting a medical history, clinical examination and radiographic evaluation. Clinically, TMJ disorders show limited lower jaw movement due to pain, crepitus, and local paraspinal

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tenderness. In radiographic examination, structural bone change can be seen. Various AI algorithms like deep learning and machine learning have been applied to image and non-image data for diagnosis of TMD [17]

Fractures:

Fractures are one of the frequently encountered condition in dental practice. Radiologists mostly diagnose fractures using CBCT and panoramic radiography. Artificial intelligence and deep learning are progressing and expanding rapidly in this field, and have shown promising applications for the detection of fractures [18]

Osteoporosis:

The diagnosis of low bone mineral density (BMD) and osteoporosis is potential area for application of AI in dental medicine including implant dentistry. Patients with osteoporosis are more vulnerable to have marginal bone loss around dental implants. Patients under antiresorptive medications are more prone for osteonecrosis of the jaws following oral surgery [19]

Oral lesions:

Used to detect and classify oral tumours and cysts with a higher degree of accuracy. Differentiation between oral cysts and tumours using 2D radiographic imaging is complex, as they have similar characteristics, it also reduces the number of referrals and provide patients with early diagnosis [20]

Orthodontics:

Useful in decision making and treatment planning by determining the need for orthodontics, extractions and orthognathic surgery. Decision making regarding orthodontic extractions is complex and specialist opinion may vary based on a clinician's experience. Teeth can be extracted to alleviate crowding, correct anterior posterior inter-arch discrepancies, and correct crossbites [20].

Dental implant:

It has emerged as one of the best treatment options to replace missing teeth. Though dental implant shows long-term success rate and survival rate, some mechanical and biological complications can occur. AI can classify the dental implant system through dental radiography because radiograph examination is commonly performed to evaluate implant treatment [21]

Forensic dentistry:

Forensic dentistry is used for age estimation, sex determination, and identification of unknown people because human dentition follows a predictable developmental sequence. Dental radiographs are well known for their poor image quality, including blurring, low contrast exposure, superimposition and distortion. Therefore, finding any relevant evidence using clinical procedures is very labour-intensive and could be affected by observers' subjective judgment. Recent studies have explored the applicability of artificial intelligence-based methods using dental radiography for forensic odontology [22]

Image quality improvement:

Usually, medical images are more prone to noise during image acquisition and transmission process. CBCT is vulnerable to noise due to its geometry. Image denoising can be done using machine learning techniques like sparse-based or filtering methods. CNN and GAN are used for noise reduction and image deblocking [22]

Dental charting:

AI along with dental radiographs can be used to complete digital tooth charting. Tooth detection can be carried out using pixel-level segmentation methods, whilst tooth charting is based on the extraction of features such as width/height teeth ratio or crown size. AI systems can have high accuracy when it comes to dental charting which would help to streamline dental appointments thereby increasing efficiency [23]

Patient Management:

Virtual assistants of AI can fulfil various dentistry related tasks with great rigor, less manpower and minimum errors compared to humans. It is utilized for different purposes like treatment planning and clinical diagnosis. Dentists get the alert about the medical history of the patient along with the habits such as the smoking and alcoholism. The patient has the emergency option in dental emergencies to give Tele assistance especially during the unavailability of the practitioner. Virtual database thus given for the patient go a long way and create better opportunities of treatment for the patient [24]

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4. Advantages of Artificial intelligence:

- Management of Abundance Data
- Diagnostic accuracy
- Standardization of procedures
- Reduce the Risk
- Perform Repetitive Jobs
- Digital Assistance
- Time-saving tool [24]

5. Disadvantages of Artificial intelligence:

- Distributional shift
- Insensitivity to impact
- Decision-making of Black box
- Unsafe failure mode
- Automation complacency
- Reinforcement of outmoded practice
- Self-fulfilling prediction
- Reward hacking
- Unsafe exploration [24]

6. Current AI studies using panoramic radiography devices:

Panoramic radiograph provides two-dimensional image and information regarding mandibular and maxillary jaw bones, existing teeth and surrounding supporting tissues. Due to its complex anatomy, superposition may occur which can be interpreted incorrectly or incompletely in certain cases. CNN-based method could be skilled to analyse and score tooth on panoramic images. Performance level of the AI system was found to be almost similar to that of the specialists' level. The early radiographic findings of odontogenic cysts and tumours are so similar that of well-trained DMFR experts. Maxillary pathologies are hindered by low bone density and other anatomical structures. It is possible that implementation of CNNs in oral and maxillofacial diagnostic imaging may reveal favourable results for clinicians. Ameloblastomas and keratocystic odontogenic tumours (KCOTs) are among the most commonly observed odontogenic tumours of the jaws. Preoperative confirmative detection of these lesions helps dental surgeons in better treatment planning. The effectiveness of a deep convolutional neural network (DCNN) based computer aided diagnosis (CAD) technique in osteoporosis has high level of consistency. Caries detection technique uses deep learning algorithms and shows high effectiveness in the detection of interproximal and occlusal carious lesions [25]

7. Current AI studies using cone beam computed tomography devices:

Cone beam computed tomography is a 3D imaging modality, which is widely used in cases where clinical examination and conventional radiographs were inadequate to provide appropriate diagnosis. CNN algorithm can detect periapical lesions. AI is used to identify and distinguish lichen planus and leukoplakia lesions using artificial neural network trained with intraoral photographs. AI technique could be useful in the automatic localization of a key landmark on CBCT images. An important advantage is the ability to make 3D measurements for cephalometric analysis. Automatic localization is not sufficient and effective in the clinical scenario. So, known techniques can be used for initial localization of cephalometric landmarks and manual correction is done for further cephalometric analysis [25]

8. Future aspects:

Current AI techniques have shown many promising performance results. It is necessary to confirm the effectiveness and consistency of these AI techniques by using relevant external data from new patients and dental institutions. Primary goal in future is to strengthen the effectiveness of AI techniques equal to a specialist and to diagnose initial pathologies that are hidden to normal human eyes [25]

9. Conclusion:

AI demonstrated high efficiency and specificity on diagnosing impacted teeth, full crowns, missing teeth, residual roots, and caries. The clinical practicability of AI framework in accuracy and efficiency is almost same or even better than the dentists with a clinical experience of 3–10 years. Improving the accuracy and speed of dental disease diagnosis and treatment planning induce better patient outcomes [26]. Dental students and practitioners should be familiar with AI and its prospective applications in Oral Medicine and Radiology. Further development, and augmentation of AI training in dental schools should be given [27]

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