Artificial Intelligence in Dentistry: From the Perspective of Oral Medicine and Radiology

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ABSTRACT
The concept of Artificial Intelligence and Robotics is emerging in the field of Dentistry. It is considered as a revolution in the field of dental health. The methods of diagnosis and management are evolving day by day. Algorithms and software are developed to study and predict the relations of different clinical conditions and help in correlation with comorbidities present in a person. AI cannot replace the human mind but helps in analyzing the condition more efficiently.
AIM: The present review article is solely based on a thorough discussion about Artificial Intelligence as an aid in applied dentistry specifically in the field of oral medicine and radiology.
Methods: Electronic databases such as Google Scholar, PubMed, ScienceDirect, and Web of Science were searched by usinga few keywords.
Keywords: Artificial Intelligence, Dentistry,Machine learning Oral medicine, and radiology.
RESULTS: More than twenty articles and few textbooks were probed and studied to accomplish the review.
CONCLUSION: The advancement of Artificial Intelligence is extremely helpful in making accurate diagnoses,faster radiographic interpretations, and treatment planning.Thus, the development of Artificial Intelligence practices is no less than a boon in the dental health care system.

I. INTRODUCTION
The human brain is an exclusive composition of intertwined neurons transmitting information to different parts of the body.[1] The extremely advanced system which can imitate the human brain very efficiently is referred to as Artificial Intelligence. It is defined as a branch of engineering and science related to computer-based knowledge and information, considered as an intelligent way of making decisions and providing responses.[2]Computer-guided diagnostic aids are gaining attention nowadays by providing an easy approach to the complicated lesions that usually remain undiagnosed on the basis of general examination alone.[3]

ARTIFICIAL INTELLIGENCE PRACTICES APPLIED IN DENTISTRY
- Managing appointments in accordance with the comfort of the doctors as well as the patients.
- Preserving the past medical and dental history along with the personal history of the patient in order to easily assess the possible complications which could occur in the management of the patient.
- Keeping a record of the diagnostic methods and interventions suggested to the Patients.[4]
- Establishment of remindersfor Patients who are under the practice of habit discontinuation like Tobacco cessation.[5].
- Equipping emergency services in cases of any dental distress and emergency teleassistance if the practitioner is not available.[4]

ARTIFICIAL INTELLIGENCE: AID IN ORAL MEDICINE PRACTICES
Artificial intelligence practices in oral medicine allow accurate diagnosis of the oral and maxillofacial region disturbances and lesions along with the various systemic conditions which can be further tested and confirmed by immunologic and histopathological studies. The "Eliza " was proposed in the year 1964 as the first interactive or communicable device to facilitate communication between a psychotherapist and patient.[6] "Dendral" was proposed later and used by pharmaceutical companies.[7] The AESOP and HERMES regulating centers were proposed and approved by FDI in the years 1994 and 1998 respectively. AESOP was based on the principle of minimal invasion thus helping the surgeons to a great extent, on the other hand, HERMSregulating center helped surgeons in a different way, by permitting their direct control over medical equipment present in the operating area by

commanding verbally.[8] The Zeus Robotic Surgical System and the Da Vinci Surgical System were introduced as a milestone in the field of surgery.[8,9]

The relation between algorithms and artificial intelligence helps us to know the practical functioning of artificial intelligence.[10] The ability to identify the comprehensive behavior of humans also indicates the same relation.

Artificial intelligence in oral medicine helps in analyzing the patients, managing appointments, and planning the treatment. Unstructured and structured data are the two main categories of healthcare analysis, where the structured data is sustained with Machine learning and Deep learning algorithms while ultrastructural data is sustained by Specialized Natural Language Processing.[10,11,12]

Around 3.58 billion individuals develop Dental caries every year.[13]Artificial Intelligence practices are also used in caries detection and prophylaxis. When we talk about oral cancer in India, around 20 individuals among every 1 lakh are affected. In such cases, data analysis and profiling of individuals can help in getting an idea of genetic predisposition for oral cancer. It can also help in getting other information like the extent of the lesion,confirmation of provisional diagnosis, and management of the most acceptable prognosis. The ability to identify the diagnostic errors is entirely based on learning from millions of 3D images and X-rays and it is considered as Artificial Intelligence assistance.

We are already aware of the fact that the disturbances or diseases of the oral cavity reflect systematically to a great extent. Artificial Intelligence interrelates such manifestations and further provides information about their mutual effect on each other. Thus, Artificial Intelligence provides comprehensive learning and assists physicians in medical record analysis.

When we talk about robotics in Dentistry, Yomi was the first surgical robot used by dental surgeons, which was approved by the U.S. Food and Drug Administration in 2017.[14] Yomi could facilitate both preoperative and intraoperative phases of oral surgeries like dental implantation in surgery.[15] Other similar but extremely realistic robots like Showa Hanako and Simroid are used presently as they provide emblematic human-like gestures.[16,17] The Geminoid F robot series could duplicate human facial expressions on the other hand HRP-4 types can imitate human sounds. Dental Nanorobots are also used to eradicate dental caries by the use of nanotechnology.[18]

ARTIFICIAL INTELLIGENCE: AID IN ORAL RADIOLOGY

The advancements in the field of radiology as well as the involvement of Artificial Intelligence prove to be a boon for radiologists worldwide. It helps in the confirmation of the provisional diagnosis predicted by mere examination. Radiographs are considered to be one of the most important diagnostic aids in dental practices. The assessment and interpretation of radiographs are the two essential steps to be performed to reach an unambiguous and most acceptable final diagnosis.[19] Both steps are based on the ability to physically recognize a radiographic image as well as the ability to differentiate between normal physiological and pathological findings.[20]

The interpretation of radiographs is itself a very sensitive step as the probability of making errors is very high, associated with the observational negligence of the radiologists which may change the entire results, further deviating from the actual diagnosis, resulting in a worsening health status. Thus, the involvement of Artificial Intelligence in this step helps to get quick interpretations in order to reach the final diagnosis as soon as possible. This also helps in eradication of minor errors hence, providing the most reliable and accurate final diagnosis. The most common and efficient method used by Artificial Intelligence in radiology is the artificial neural network (ANN).This computer system imitates the function of the human brain. ANNs are considered to be the predominant type of Artificial Intelligence which is based on supervised learning by the comparison of the predicted results.[21,22] It can also be based on unsupervised learning in which calculations of their interactions are transformed through elaboration and interaction with the input data.[22,23]The unsupervised learning can provide a more correct diagnosis, allowing ANN to make out the knowledge of simple cases in order to solve the difficult ones.

In the field of oral radiology, specific algorithms are made that further helps to determine most suitable treatment options. In this way, more efficient and accelerated diagnosis is obtained with the help of Artificial Intelligence.[24]

The neural network through the X-rays, panoramic and lateral cephalogram images identifies the major anatomical landmarks, interventions, and diseases like crown, implants, periapical pathologies, restorations, root canal treatment, etc., providing the most appropriate diagnosis.

ARTIFICIAL INTELLIGENCE AS AN AID IN DETERMINING VARIOUS ANATOMICAL LANDMARKS

Cephalometric landmarks are obtained by the Convolutional neural network (CNN) which allows exact edge recognition, edge-based, region-based, and knowledge-based algorithms. CNN helps in absolute detection of anatomical landmarks using pixel-by-pixel expansion. [25] It can also be used with CT and MRI to understand the variations that could remain unnoticed.[26]
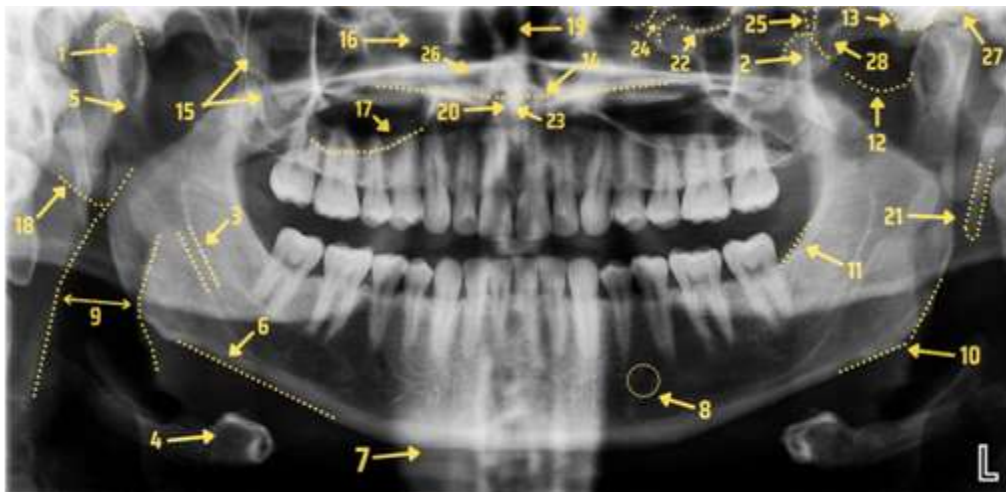

Fig 1:Representation of Anatomical landmarks on Orthopantomogram

1. Mandibular condyle	15. Zygomatic process of maxilla
2. Coronoid process of mandible	16. Anterior aspect of concha
3. Mandibular canal	17. Floor of maxillary sinus
4. Hyoid bone	18. Ear lobe
5. Neck of the condyle	19. Nasal septum
6. Inferior border of mandible	20. Anterior nasal spine
7. Superimposed shadow of cervical spine	21. Styloid process
8. Mental foramen	22. Lower orbital margin
9. Airway shadow	23. Intermaxillary suture
10. Mandibular angle	24. Infraorbital canal
11. External oblique ridge	25. Pterygomaxillary suture
12. Sigmoid notch	26. Ghost image - Hard palate
13. Articular tubercle	27. Articular fossa
14. Hard palate	28. Zygoma

Table 1: Anatomical landmarks of OPG

ARTIFICIAL INTELLIGENCE AS AN AID IN DETERMINING DENTAL CARIES

The detection of interproximal decay is done by using several bitewing radiographs. Lee et. al observed that among 3000 radiographs, the efficiency of determining dental caries in premolars, molars, and both premolars and molars are 89%, 88%, and 82%,respectively.[27] The diagnosis of dental caries in bitewing, periapical as well as panoramic radiographs is based on deep learning networks.[28]
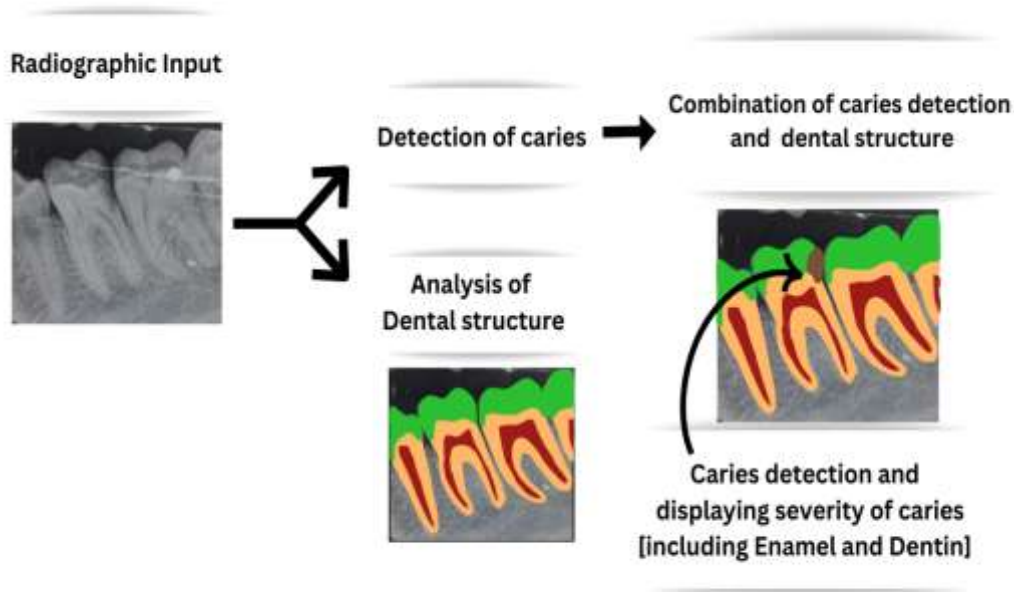
Fig 2: Early caries detection by using Intraoral Periapical Radiograph.

ARTIFICIAL INTELLIGENCE AS AN AID IN DETERMINING BONE LOSS

The pathologies of periodontium are effectively diagnosed with Artificial neural network (ANN). Koris et.al stated that neural networks provide around 81% accuracy.[29]
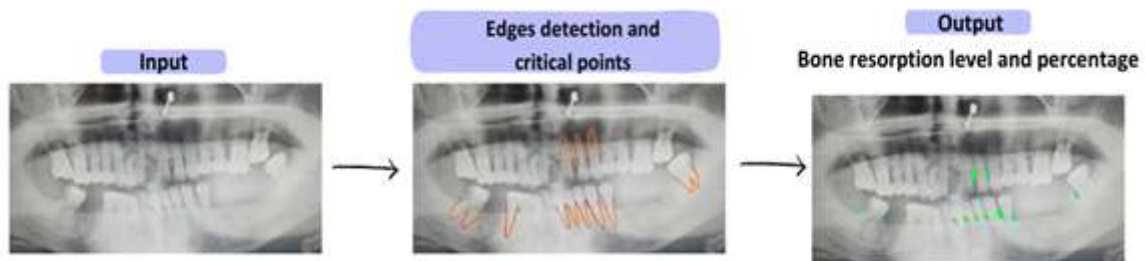

Fig 3: Determining the level and percentage of Bone Resorption in Orthopantomogram by using Convolutional neural network [CNN].

[Markings in red indicates physiologic bone crest level, orange indicates existing bone level and green indicates areas with bone loss.]

ARTIFICIAL INTELLIGENCE AS AN AID IN ROOT CANALTHERAPY

The determination of correct workinglength is an essential component of root canal therapy. [30]Several methods like tactile sensation, electronic apex locator, intraoral periapical radiographs, and CBCT are used for the determination of working length.Sahgiri et al.[31-35] assessed the accuracy of working length by an artificial neural network [ANN] using a human cadaver andalso determined minor apical foramina with an accuracy of 96%as compared to endodontists which is 76%, concluding ANN to be a highly accurateapproach in determining working length.

ARTIFICIAL INTELLIGENCE AS AN AID IN FORENSIC ODONTOLOGY

Artificial Intelligence has been extensively utilized in Forensic medicine as well as odontology.It has proved to be highly effective in determining the biological age and gender of any population,prediction of mandibular morphology, and bite mark analysis.[36]

ARTIFICIAL INTELLIGENCE AS AN AID IN DETERMINING VARIOUS PERIAPICAL PATHOLOGIES

Al helps in determining various periapical pathologies like periapical cysts, abscesses, and granulomas with an accuracy of about 92.8%by locating the boundaries of the lesion which provides the correct way to the diagnosis.[37]Further, Flores et al. distinguished granulomas from periapical cysts with the help of CBCT images which came out to be very crucial in the recovery of periapical granulomas post root canal therapy without any surgical intervention.[38]

Fig 4: Determining periapical pathologies with the help of Artificial Intelligence.

ARTIFICIAL INTELLIGENCE AS AN AID IN DETERMINING POTENTIALLY MALIGNANT CONDITIONS

AI helps in early detection of oral cancer. ANN helps in the identification of cervical lymph node metastasis which further makes the prognosis of head and neck cancer better. The Convolutional neural network (CNN) provides 78.2% accuracy, 75.2% sensitivity, and 81% specificity which can be compared with expert radiologists.[39]
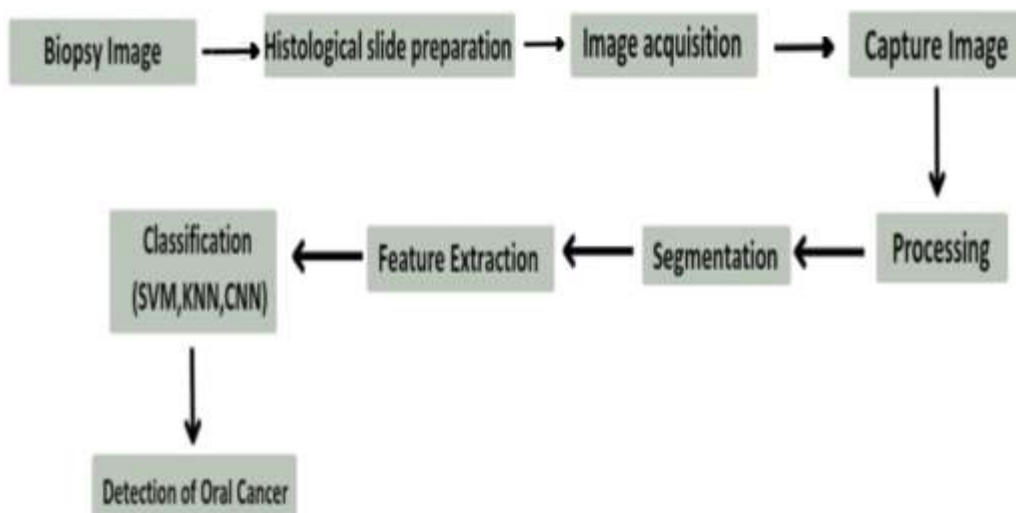

Fig 5: Artificial Intelligence in Early Detection of Oral Cancer.

II. LIMITATIONS OF ARTIFICIAL INTELLIGENCE

Data protection and organization of medical and dental records aresome of the reasons that AI not been fully adopted in dentistry. These datasets are often small and lack structure as compared to the datasets in AI practices. Data is patient-specific, complex, and sensitive. Sampling of such data may lead to selection bias with overly sick,overly healthy, and overly affluent individuals being overrepresented.[40]

According to Schwendicke et al. data processing, calculations, and result validation may be insufficiently replicable and difficult in research with Artificial Intelligence.[41] There is no gold standard or agreement on labeling any data as well as merging different labels.[42]

Maddox et al.stated that the outcomes of Artificial Intelligence in dentistry are often not

applicable promptly as it provides partial information which is not sufficient in decision-makingin healthcare system.[43]

III. CONCLUSION

According to the number of theories documented so far, the human mind has been a major topic of discussion. As we are heading towards the future, the possibility to train our computers and build realistic machines is getting stronger and acceptable. The advancement of Artificial Intelligence is extremely helpful in making correlations and results. AI is widely used in dentistry nowadays. It is helpful not only for patients but also for the healthcareproviders. AI is increasing the accuracy rate in making the diagnosis and also helping to get fast interpretations. Artificial Intelligence proved to be an accessory process helps in making an appropriate diagnosis which in turns aids in treatment planning and health management. AI is providing a shift of radiographic interpretations from subjective observations to more analytical results. Thus, the development of Artificial Intelligence practices in oral medicine and radiology is no less than a boon in the dental healthcare system.

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