ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 7, Issue – 2, March – 2024, Page No. : 119 - 125

Oral and Maxillofacial Radiology and Artificial Intelligence- An Overview

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Citation of this Article: Dr. Isha Thakur, "Oral and Maxillofacial Radiology and Artificial Intelligence- An Overview", IJDSIR- March – 2024, Volume –7, Issue - 2, P. No. 119 – 125.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Artificial intelligence (AI) is defined as the capability of a machine to imitate intelligent human behaviour to perform complex tasks, such as problem solving, object and word recognition, and decision- making. Smart home devices, mathematical calculations, weather forecasting, autocorrection in word processors, texting apps etc., facial recognition to unlock phones, speech recognition, medical diagnosis etc. illustrate the diverse applications of AI across different domains, showcasing its ability to perform tasks that traditionally required human intelligence.AI plays a crucial role in the automated detection of abnormalities and pathologies, diagnosis of disease and evaluation of prognosis. The integration of AI in clinical medicine holds great promise for enhancing diagnostic accuracy, improving patient outcomes, and optimizing healthcare processes. In radiology, the digital and standardized nature of radiological images such as X-rays or MRIs, makes them particularly amenable to AI applications which has further led to significant advancements in the development of AI tools for medical imaging, with the potential to revolutionize diagnostic processes and improve patient care in the field of radiology and beyond. Within the domain of Oral and Maxillofacial Radiology (OMFR), image and patient recognition are crucial. Despite the current high initial investment costs and the risk of inappropriate assumptions in real-life clinical scenarios, AI studies related to OMFR have shown promising results. Yet, continued research in the AI field has the potential to significantly contribute to Oral and Maxillofacial Radiology, but a cautious and evidence-based approach is crucial for its successful integration.

Keywords: Artificial Intelligence, Dental Caries, Restorations, Pathologies, Bone Density.

Introduction

Artificial intelligence (AI) is defined as the capability of a machine to imitate intelligent human behaviour to perform complex tasks, such as problem solving, object and word recognition, and decision- making.[1, 2] Indeed, the birth of artificial intelligence (AI) can be traced back to the Dartmouth workshop in 1956, where the term "artificial intelligence" was coined. The founders envisioned AI as a field that could explore various avenues of research, including neural networks, natural language processing, the theory of computation, and other intriguing topics.[3] While artificial intelligence has indeed encountered challenges, it's important to note the significant progress made over the years. Advances in computational power, the availability of vast datasets, and improved algorithms have propelled AI into various fields, showcasing its transformativepotential.[4] Smart home devices, mathematical calculations, weather forecasting, auto correction in word processors, texting apps etc., facial recognition to unlock phones, speech recognition, medical diagnosis etc. illustrate the diverse applications of AI across different domains, showcasing its ability to perform tasks that traditionally required human intelligence. AI continues to advance, opening up new possibilities for innovation and problem-solving in various fields. AI models in clinical medicine can analyse vast amounts of patient data to identify patterns and factors contributing to disease risk. AI plays a crucial role in the automated detection of abnormalities and pathologies, diagnosis of disease and evaluation of prognosis. The integration of AI in clinical medicine holds great promise for enhancing diagnostic accuracy, improving patient outcomes, and optimizing healthcare processes.[5] In radiology, the digital and standardized nature of radiological images such as X-rays or MRIs, makes them particularly amenable to AI applications. This has led to significant advancements in the development of AI tools for medical imaging, with the potential to revolutionize diagnostic processes and improve patient care in the field of radiology and beyond.[6]

Artificial Intelligence (AI) is a broad field that encompasses various subfields, and two major categories within AI are Machine Learning (ML) and Deep Learning (DL) and Convolution Neural Networks (CNNs).[7]fig.1

Machine Learning

Machine learning serves as a pivotal element within the realm of artificial intelligence (AI), imparting the ability to computers to emulate human thought processes—learning and evolving based on prior experiences. This mechanism hinges on data exploration and pattern recognition, demanding minimal human intervention. Machine learning excels at automating tasks aligning with discernible data patterns or predefined rule sets.[5]

Machine learning uses two primary techniques:

1. Supervised learning
2. Unsupervised learning

In the realm of machine learning, supervised machine learning facilitates the acquisition or generation of data derived from a previous machine learning implementation. This approach is particularly intriguing as it mirrors the process of human active learning. In supervised learning, the computer is equipped with a set of labelled data points known as a training set, forming the foundation for its learning and predictive capabilities.

Unsupervised machine learning plays a role in unravelling various uncharted trends within outcomes.

Operating solely with unlabelled samples, unsupervised learning endeavours to discern intrinsic structures inherent in the results. Clustering and dimensionality reduction stand out as two prevalent unsupervised learning activities. Clustering involves arranging data points into meaningful clusters, ensuring that elements within a specific cluster share common characteristics.[9]

In the supervised learning process for diagnostic images, the crucial task of labelling or annotation falls upon expert radiologists. They play a pivotal role in providing the necessary guidance and categorization to facilitate the training of machine learning algorithms on medical imaging data.[10]

Deep Learning

Deep learning algorithms operate on the fundamental concept of automating the extraction of representations from data. Deep learning algorithms harness vast amounts of unprocessed data to autonomously extract intricate patterns. Rooted in the broader field of artificial intelligence, these algorithms strive to emulate the human brain's ability to observe, analyse, learn, and make decisions especially when tackling exceptionally complex problems.[11] fig.2

Convolutional Neural Networks (CNNs)

A form of deep learning architecture, has played a pivotal role in recent advancements in artificial intelligence. Their predominant application lies in the analysis of expansive and intricate images. Deep neural network learns from data lowering error between prediction and ground truth labels during repetitive step. Error minimization occurs gradually using differentiation of the error of mini batch (partitioned data set).[4]

AI In Radiology

Certainly, Convolutional Neural Networks (CNNs) have proven to be highly effective in various tasks within the field of radiology, including classification, detection, and segmentation. Let's delve into each of these applications:

Classification: Presence or Absence of Disease: CNNs can be trained to analyze medical images and determine whether a particular pathology or disease is present or absent.

Type of Malignancy: CNNs excel at categorizing and classifying different types of malignancies. This involves training the network on labelled data that includes examples of various malignancy types, allowing the model to learn and differentiate between them.

Detection

Lesion Detection: CNNs are highly effective in detecting lesions or anomalies in medical images. Whether it's identifying tumors in radiographic images or other abnormalities in different modalities (CT scans, MRIs, X-rays), CNNs can learn patterns and features indicative of such conditions.

Anomaly Detection: Beyond specific lesions, CNNs can also be used for general anomaly detection, identifying any irregularities in the images that may require further attention.

Segmentation: Tumor Segmentation: Segmentation involves identifying and outlining specific regions or structures within an image. In radiology, this can be applied to segment tumors or other structures of interest. This is crucial for precise diagnosis, treatment planning, and monitoring.

Organ Segmentation: CNNs can be trained to segment different organs or tissues within medical images.

This segmentation aids in quantitative analysis and provides a more detailed understanding of the spatial distribution of abnormalities.

The strength of CNNs lies in their ability to automatically learn hierarchical features from data, making them well-suited for tasks involving image analysis. The continuous advancements in deep learning and the availability of large annotated datasets contribute to the improvement and widespread adoption of CNNs in the radiology field. Fig.3 shows classification, detection and segmentation in dental caries.[12]

AI in Oral and Maxillofacial Radiology

Automated Analysis: It works as - A. Training set is built (involves the meticulous curation of a certain dataset from vast available number of radiographs, by clinical experts). B. the annotation of the training data is done by an oral radiologist manually. C. AI software is trained, using those datasets to create a adapting dataset. D. Accuracy of the dataset is evaluated in fresh/testing set of radiographs which have not been evaluated previously. This way AI helps automated analysis of teeth detection and teeth numbering.[13]

Anatomic Landmarks Detection: CNNs play a crucial role in improving the accuracy of anatomical detection through meticulous pixel-level analysis and the application of knowledge-based algorithms to find cephalometric landmarks. It can help to locate landmarks which are difficult to detect by a naked human eye due to low contrast, overlapping or of bad quality.[14]

Detection of Dental Caries: Leveraging pre-trained deep learning networks for the diagnosis of dental caries in various radiographic types like bitewing, periapical and panoramic radiographs, offers a powerful and efficient approach. Lee et al found that within 3000 dental radiographs, the accuracy of identifying dental caries in premolars, molars, and both premolars and molars are 89%, 88%, and 82%, respectively.[15]

Detection of Dental Restorations: In two- dimensional (2D) radiographic images such as periapical and panoramic photographs, due to structures overlap, it is often difficult to clearly distinguish and outline three-dimensional (3D) anatomical structures. AI system can overcome this by using machine learning by automatic detection and classification of dental restorations in panoramic radiography (Fig.4).16

Periapical Pathologies Detection – AI can help in detection of periapical pathologies such as periapical cyst, granuloma as abscess. AI can accurately locate the exact boundaries of the lesions and enable proper detection. Also, in early detection of peri-implantitis with appropriate interventions, these systems are poised to play a pivotal role in years to come.[17]

In a study, Periapical lesion detection has been carried out by a dataset input of more than 170 patients' intra-oral Periapical radiographic images. On pre-processing through resizing, augmentation and gray scaling, the modified image was conveyed as input to the present hybrid model. The model detected the anomalies with an accuracy of 95.85%. Further for refinement in endodontic treatment including identification of various abnormalities, root-fractures, working length measurements, repeat root-canal success rate, etc., new models have been proposed.[18]

Detection of Bone Loss: Artificial Neural Networks (ANN) are anticipated to assist radiologists in mitigating cognitive bias, streamlining diagnostic efforts, and subsequently elevating the diagnostic accuracy associated with periodontal pathology. A study has showed higher diagnostic performance, with an accuracy of 81%, than individual clinicans, who showed an accuracy of 76%, in the radiographic detection of periodontal bone loss (P=0.067).19

Detection of oral cysts and tumours and cancers: AI can help in early diagnosis of oral cysts, tumours of both jaws on panoramic radiograph. Fig.5[20]

It will play a major role in early diagnosis of oral carcinomas, cervical lymph nodes metastasis that results in better prognosis of head and neck cancers. A study showed that AI improved prediction of cancer survival and helping experts in selecting better treatment options and reducing unnecessary treatment protocols.[21]

Other different uses of AI in maxillofacial radiology:

1. Bonedensity evaluation to predict osteoporosis using OPGs.
2. Computer based digital subtraction imaging.

3. Dimensional orthodontics visualization using patient models and OPGs.
4. Forensic dental imaging [22]

Conclusion

AI holds the potential to transform healthcare and dentistry, generating heightened interest among scientists due to recent advancements. Within the domain of Oral and Maxillofacial Radiology (OMFR), image and patient recognition are crucial. Despite the current high initial investment costs and the risk of inappropriate assumptions in real-life clinical scenarios, AI studies related to OMFR have shown promising results. It is essential to acknowledge the complexity of the human physiological system, positioning AI as a supplementary method rather than a substitute for human knowledge, capabilities, and decision-making skills. Moreover, the diagnostic performance of AI models can vary depending on the algorithms employed.

Ensuring consistency and effectiveness necessitates thorough validation using accurate and representative images from diverse sources before implementing these techniques in real clinical settings. In conclusion, continued research in the AI field has the potential to significantly contribute to Oral and Maxillofacial Radiology, but a cautious and evidence-based approach is crucial for its successful integration.

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Legend Figures

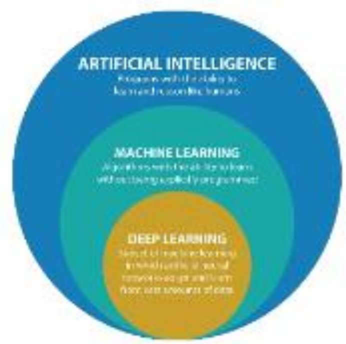

Figure 1: Google source represents subfields of artificial intelligence.

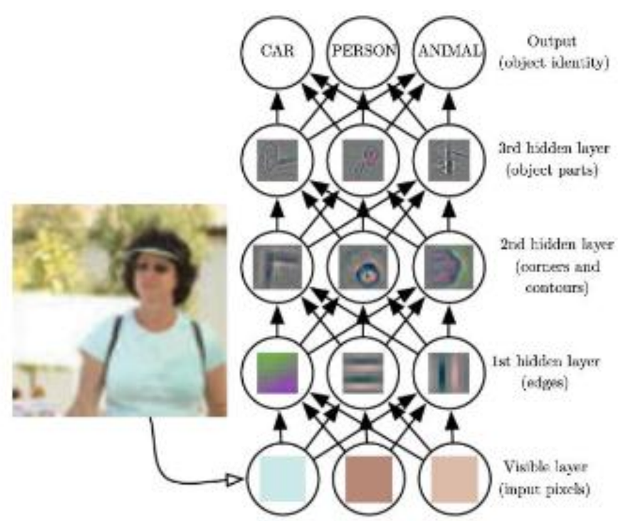

Figure 2: Understanding deep learning, pic source Google

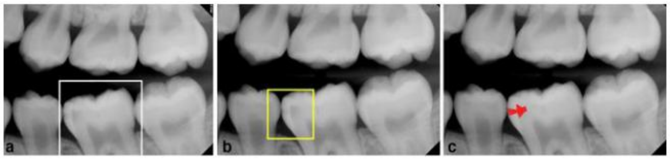

Figure 3: a. Dental caries is present in the rectangular box on the image (classification). b. Dental caries is detected in the square box (detection). c. A dental caries is segmented on the image (segmentation).

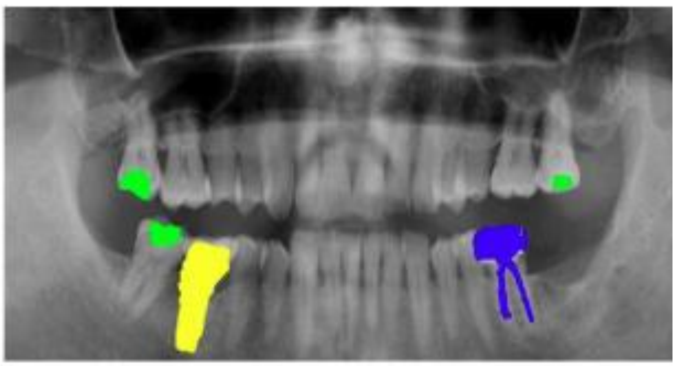

Figure 4: Automatic classifications of dental restorations. Green-amalgam fillings, blue-RCT+core+crown, yellow- dental implant+crown.

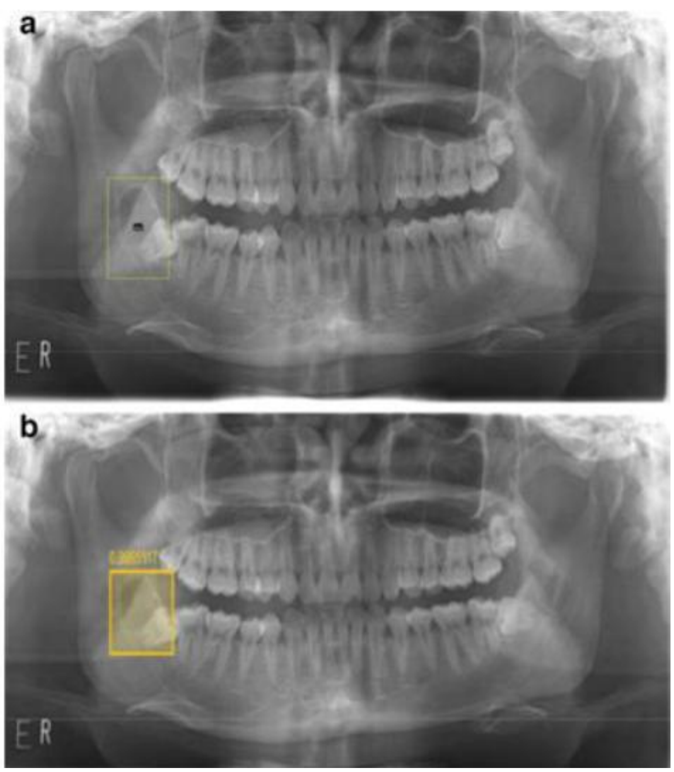

Figure 5: a. Odontogenic keratocyst (OKC) is labelled at the right posterior mandible on a panoramic radiograph. b. The lesion is automatically detected using deep learning.

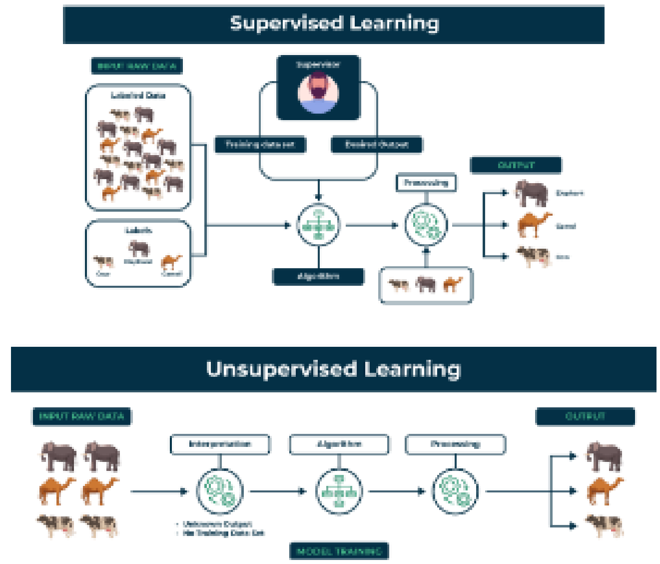

Figure 6: Supervised learning and Unsupervised learning - source -Google