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Review Article

Role of artificial intelligence in clinical practice

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ABSTRACT

Artificial Intelligence (AI) has revolutionized numerous fields, including dentistry, offering transformative potential in diagnosis, treatment planning, and patient care. With its ability to replicate human intelligence and process complex data sets, AI provides innovative solutions across various dental specialties. This review discusses AI's role in clinical dentistry, emphasizing its applications, benefits, limitations, and future prospects in fields like radiology, orthodontics, periodontics, prosthodontics, and endodontics. Currently, the application of convoluted neural network (CNN)s is more common in the dental field. Moreover, it offers a glimpse into its applications on integration with virtual reality, augmented reality and metaverse.

1. Introduction

Artificial intelligence (AI) has been one of the greatest contributions from the recent industrial evolution and marks a significant advancement in the new digital era. It is being considered as the fourth most important technological revolution world over.[1]

AI works with the help of data analysis, and this data is available from the electronic devices that almost everyone has. Artificial intelligence is expanding and reaches almost all fields. Essentially, artificial intelligence replicates what human intelligence does. It requires and assimilates human expertise, learns from it, and delivers outcomes comparable to human intelligence. We have seen AI in various fields such as robotics, automobiles, and others. Its role in medicine and dentistry is noteworthy. It is a valuable tool that makes use of multi-modal data, which means data from various aspects, and it has the necessary hardware, computing capacity, algorithmic research, and input data. Speaking of dentistry, artificial intelligence has great potential, which is why many studies are undergoing to elaborate on its usage in this field.

"In the digital age, dentistry is undergoing a paradigm shift, with artificial intelligence acting as a catalyst for transformative change, driving us towards a future where oral health is truly personalized and proactive." - Dr. Olivia Smith

AI is not new today, it was introduced in 1950s by John McCarthy, and is already making a significant leap in our everyday life, making time consuming tasks quicker, thereby increasing work efficiency. AI has developed as an amalgamation of the fields of science and engineering, where in the machines are taught to carry out tasks or operations that require intelligence like humans. The following (Figure 1) gives a glimpse of the categories

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and subsets of artificial intelligence which include machine learning (ML) as a subset.

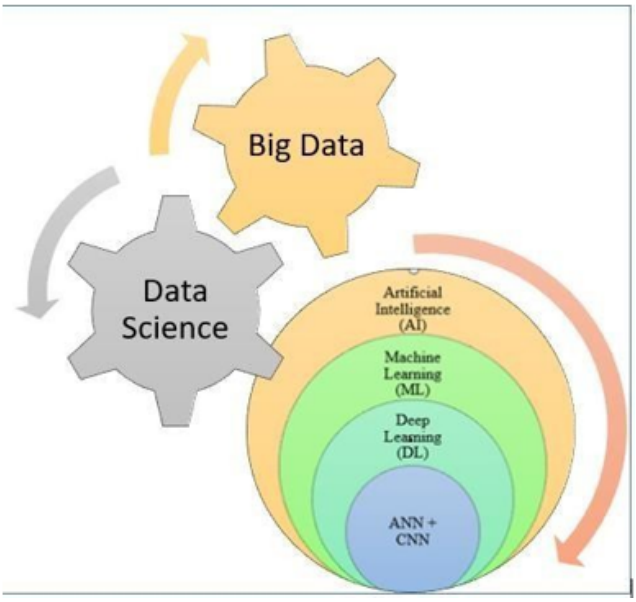

Figure 1: Depicting the interrelationship between AI and Big Data and Data Science and the subsets of AI (Adapted from[2]) such as ML, DL and the prominent role of artificial neural network (ANN) and convoluted neural network (CNN) convoluted neural network

1.1. How does AI work?

The method by which machine is able to learn is referred to as deep learning (DL) which includes artificial neural network (ANN) and convoluted neural network (CNN). The following flowchart (Figures 2 and 3) explains the role of each component involved in artificial intelligence.

Machine learning (ML) methods can be categorized into three types of learning which can be supervised, unsupervised and reinforced. The first type, is used in classifying or predicting tasks, while, the second type aids to realize concealed patterns in data. Reinforcement learning maximizes rewards based on previous versions of learning. Deep learning (DL) utilizes algorithms, by making use of CNNs which can automatically extract relevant information from input data, eliminating the need for manual feature identification and extraction. DL has shown promise in medical disease diagnosis and personalized recommendations for treatment. For instance, in orthodontics, AI-based multi-modular diagnostic systems have emerged, such as Diagnocat Ltd., which uses CNNs for precise dental diagnostics. DL models aid in caries detection and endodontic involvement by detecting periapical lesions in CBCT images which may aid clinical workflows.[2]

The question to ponder is, whether we really require AI in dentistry? And if so, what are the limitations in the current dental practice or education which can be improved with

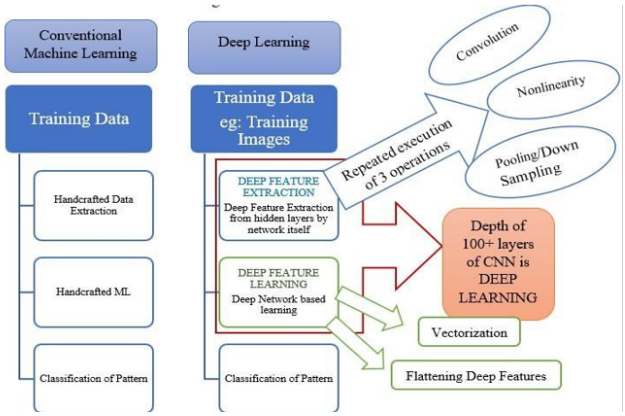

Figure 2: The steps involved in machine learning and deep learning (Adapted from[3]). The flowchart depicts how machine is trained by training it by data which is extracted and classified into a pattern in conventional machine learning followed by deep learning mode which makes use of images for training and extraction and identification of data from it.

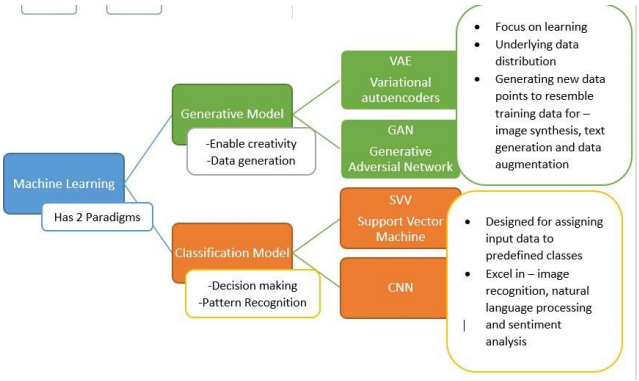

Figure 3: Paradigms in machine learning (Adapted from[2,3]) showing the two ways generative and classical models, in which machine learning can help in creating data and make decisions by recognizing patterns respectively.

AI. Dentistry has nine specialties and with technological advancements additional specialized fields such as – digital dentistry, implantology, orofacial pain etc. have emerged. It is imperative to know the role of AI in each of these specialties.

1.2. Importance of AI

The traditional techniques used in the field of dentistry in terms of dental education, practice management, treatment, diagnosing patients and handling dental emergencies like trauma are facing challenges. It is here, that the role of AI becomes important.[2]

AI is of value in a dental practice or academic setting by assisting in pretreatment tasks such as appointing patients, maintaining follow up visits, minimizing manual paperwork

and insurance, and providing telephonic assistance in cases of dental emergencies during pandemic situations. Technology of AI is such that it can be used for patient screening and safeguarding dental staff's health, by collating data on key risk factors of disease. However, the downside of these benefits is the cost involved.[2]

1.3. What is role of AR/VR/MV?

In the present times, AI alone is not enough. It is unfair to not mention the role of augmented reality (AR), virtual reality (VR) and metaverse (MV) in this regard. AR was introduced four decades back and is now on the forefront due to the development in the computer technology and high demand. AR provides an immersive and interactive experiences in real-world environments. It usually requires portable computers/tablets/head-mounted displays, and smart glasses, which are all equipped with sensors, such as cameras, accelerometers, gyroscopes, and depth-sensing units, to determine accurate position and orientation. The data provided from these is used by the AR software to produce 3D models synthesized to be overlaid on the real world while reacting to user commands.[3] VR is a simulation of the real-world environment or scenarios generated by a computer, giving the users a sense of being present in the scenario.[4] MV introduced by Neal Stephenson is a computer-generated virtual world, where virtual users in their Avatar form can gain access to experiences which are unattainable in real world.[5]

2. Discussion

AI is transforming every specialty of dentistry, making it an indispensable tool for clinicians. Much like the adoption of CBCT and intraoral scanners in the digital dentistry era, AI is becoming integral to streamlining workflows, improving diagnostic accuracy, and personalizing patient care. As its applications expand, AI will continue to redefine dentistry, ensuring it becomes an essential part of everyday practice. The salient features and applications in dental specialties is mentioned briefly below.

2.1. Role of AI in oral radiology and oral surgery

Radiology in dentistry is essential in diagnosing fractures, bone loss, caries and pupal involvement. AI helps in improving the reports and diagnosing facial fractures. Trauma cases in Oral and maxillofacial unit, require immediate diagnosis to provide timely treatment to prevent further morbidity and mortality. Many times, delay in treatment has been attributed to discrepancy between radiologist and surgeon. AI helps in precise assessment of fractures using CNN. AI models are trained to identify complex fractures by taking data from panoramic, CT or CBCT imaging. Non-contrast CT scans have been recommended for deep learning using AI models like, ResUNet++ for facial and cranial bone segmentation with YOLOv4 for expedited fracture identification. It has been observed that Faster region-based CNN (Faster R-CNN) provides best precision, DenseNet-169 provides good accuracy of multiclass classification. ResNet50 is used for maxillofacial fractures. Faster R-CNN framework has been developed for detection of skull fractures. U-Net and YOLOv4 networks have been used to enhance mandible fractures detection by a great degree. These AI models can aid in the diagnostic efficiency of novice radiologists. It is essential to have a comprehensive understanding of the anatomy by the dentists in order to train the models in learning. Challenges with AI adoption include limited diversity in data available for training AI models which may result in biased results and over estimation of findings and limit its application in the general pool of population. Additionally, quality of the image or scatter patterns can impact AI performance. AI models are increasingly used to foresee the possibility of nerve damage during mandibular third molar extractions using panoramic images. AI also helps in creating simulations, which can reconstruct the sequence of events that might have resulted in trauma. It also enables the calculation of force and impact that caused the fractures. AI base simulation can be used for patient education.[2]

2.2. Role of AI in orthodontics

In the field of orthodontics, AI plays an essential role in diagnostics and treatment planning by aiding in cephalometric evaluation, determining skeletal age and even analyzing temporomandibular joint. AI can be used for monitoring patient from a distance- telemonitoring. Some AI-based programs which can identify the cephalometric landmarks include WeDoCeph, WebCeph, and CephX. These can identify, compute and generate cephalometric reports. CNN- based models have shown high accuracy in cervical vertebral maturation assessments required for growth estimation. Some studies on decision making in cases requiring extraction have shown promise using AI algorithm. A 3D model has been developed to identify patients, categorize them according to their risk levels, and produce simulations for orthognathic surgery treatment plans automatically. Similarly, AI has shown potential in planning for orthognathic surgery. Still, the application of these algorithms calls for implementation with manual validation but with caution due to risk of bias. Application of AI requires continuous learning, governance, and ensuring patient privacy.[6]

2.3. Role of AI in periodontology

AI can identify common dental diseases, such as dental caries, periodontal disease, osteosclerosis, odontogenic cysts/tumors and maxillary sinus pathologies on a radiology

image. Currently, applications based on AI have been developed which can provide an AI generated report for better patient communication and treatment acceptance. AI models have shown high precision and dependability in automatic diagnosis of periodontal bone loss and staging periodontitis via DL methods. Neural networks in periodontology aid in precise bone loss assessment. AI and 3-D printing has given rise to the concept of bioprinting which can essentially print living tissue or scaffolds for regenerating hard or soft tissues. PerioSim is a modality which combines AI and robotics to measure periodontal pockets.[7,8]

2.4. Role of AI in implantology

AI technology is also utilized in enhancing the design of dental implants, adjusting implant characteristics like porosity, length, and diameter, as well as forecasting the success of dental implants and their integration with the bone. Nevertheless, due to the elevated risk of bias and chance of overestimation of accuracy, complete reliance on AI technology for identifying oral pathologies is not advisable, prompting the need for further advancements. In the realm of image analysis using AI, ANN can play a role in classification, detection, and segmentation. This involves the process of transforming the radiographic raw data to make it more representative, standardized and reducing noise and errors in radiographs. Data augmentation which involves skewing, flipping and rotation, is then used to train the learning model.[2,9,10]

2.5. Role of AI in restorative and endodontics

AI advancements can assist in endodontics by analyzing root canal anatomy, detecting root fractures, and periapical lesions. ANN models have also been used to detect periapical lesions and vertical root fractures. Moreover, interproximal caries is easily missed during diagnosis and AI has a role in early detection of these interproximal lesions.[11–14] BothCNN and ANN have shown great promise in improving diagnostic precision in endodontics. These technologies can accurately evaluate root canal anatomy. Based on study by Poswar et.al[15], AI can be used to analyze the gene expression for radicular cysts and periapical granulomas highlighting the role of biological processes in differentiating the two lesions.[15,16]

2.6. Role of AI in pediatric dentistry

In pediatric dentistry, AI can detect dental caries especially proximal caries and impacted teeth on radiographic images.[13]

2.7. Role of AI in prosthodontics

In the field of prosthodontics, AI models are used to enhance crown designs with better marginal fit, predict the life of the prosthesis, and color matching. RaPid, a design assistant has been developed for calculating facial measurements for better esthetic prosthesis.[11–14] In terms of replacement of teeth using implant supported prosthesis, CNN can be utilized for quick identification of dental implant brands on panoramic radiographs, to check quality of the osseointegration between implant and the bone. AI is being actively used to measure the peri-implant bone loss.[16] Machine learning can be used as an educative tool for dental technicians to train them for sculpting the proper morphology of prosthesis.[17] AI can be used in quality control in clinic steps, such as checking the crown preparation, the crown designed, identifying a dental crown from an image to predicting the debonding potential of the cemented crown.[18] In vitro studies have been conducted exploring the role of robotics in prosthodontics by using phantom models for tooth preparation in creating complete crowns, veneers, and tooth arrangement for complete dentures.[19]

2.8. AI and robotics

AI technology when combined with robotics is gaining a range of applications in dentistry. Robots are being developed who can create complete dentures, perform teeth arrangement and prepare tooth for crown. YOMITM is the first FDA approved navigation robotic system for accurate implant placement. Waseda Asahi Oral-rehabilitation robot No. 1 (WAO1) can aid in TMJ disorders by massaging masseter muscle, use of robotic articulator using by robot named ‘Bionic Jaw Motion’.[20]

2.9. Perception of AI in among dentists

A study by Baby D et al.[21] explores the role of robotics and AI in oral health education, focusing on the knowledge, perceptions, and attitudes of dentists in India. It highlights the potential of AI and robotics to revolutionize dental education by enhancing teaching methods, improving learning outcomes, and fostering patient care. The study also addresses the level of awareness and acceptance of these technologies among dental professionals, emphasizing the need for integration into dental curricula and training programs to prepare for future advancements in dentistry.[21]

"In dentistry, AI is not just a tool; it’s a catalyst for innovation, driving us towards a future where oral health is more accessible and personalized than ever before." - Dr. Sarah Patel

2.10. Future trends

The future of AI in dentistry is boundless, particularly with its integration into AR, VR, and the MV. AR has become a pivotal tool in enhancing surgical visualization, providing real-time overlays of critical anatomical structures during procedures. This capability not only enhances precision but also reduces procedural errors. Similarly, AI has revolutionized dental training by offering virtual patient simulations that replicate clinical scenarios, enabling students to refine their skills in a risk-free environment.[4]

The metaverse extends this transformation by creating immersive virtual spaces for global collaboration and education. Dental professionals and students can engage in shared virtual environments to exchange knowledge, conduct research, and collaborate on complex cases—bridging geographical barriers. AI-powered AR applications, for instance, can overlay 3D anatomical structures during assessments, offering real-time visual guidance for accurate diagnoses and treatment planning. These innovations make dental education and clinical practice more accessible and interactive.[4]

Moreover, predictive analytics fueled by AI is driving personalized oral healthcare. By analyzing patient data—such as dental history, genetic predispositions, and lifestyle factors—AI can predict potential oral health issues and recommend tailored preventive measures. This proactive approach helps mitigate chronic conditions like periodontitis and dental caries. Case studies demonstrate that AI-based tools can identify patterns in patient data, enabling clinicians to deliver more precise and personalized care.[4]

Together, these advancements position AI, AR/VR, and the metaverse as indispensable tools in modern dentistry, shaping a future where education, diagnostics, and treatment are more efficient, precise, and collaborative.

3. Conclusion

In conclusion, the success of AI surpasses human expertise as it leverages computer technology, computing capacity, and vast databases, with high computational power to train algorithms. It involves the judicious integration of systemic data assessment to arrive at diagnoses. AI assists in storing, analyzing data, and recognizing patterns to improve diagnoses, all accomplished swiftly. On one hand, AI, coupled with machine learning, could address the aforementioned points, but certain challenges remain, such as data inaccessibility and discrepancies in diagnoses from different clinicians. In some cases, data privacy protection may hinder accessing broader datasets, leading to potential bias. Medical data pose challenges as diagnoses rely on multiple sources and face limited interoperability due to ethical concerns and data protection issues. They often lack systemic allocation, and data from specific regions may result in precise but inaccurate outcomes, inapplicable elsewhere. Hence, the utilization of artificial intelligence alongside human expertise is crucial, as both complement each other, maximizing results and benefiting clinicians. Integration of AI with AR, VR, MR will be the new future modalities which will require upskilling from all stakeholders to capitalize on its benefits.

4. Source of Funding

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5. Conflict of Interest

None.

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