Artificial Intelligence & Its Contemporary Applications in Dentistry

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Abstract:
Artificial intelligence (AI) has been used in a variety of ways in healthcare. It is a field of both engineering and science,associated with the perceptive of intelligent behavior, and creating artifacts that replicate such behavior. Technology has been the biggest innovation in every industry, Dental care is no different. Artificial Intelligence can serve as a useful modality in diagnosis and treatment of lesions of the oral cavity and can be employed in screening and classifying suspicious altered oral mucosa undergoing premalignant and malignant changes. This field can be explored tremendously for easy diagnosis, proper treatment and satisfying outcome.

Keywords: Artificial Intelligence, Artificial Neural Networks, Deep learning, Machine Learning.

1. Introduction

The human brain is a complex mesh of interconnected neurons transmitting signals throughout the body parts.[1] The human brain is thought to be inimitable; making the scientists and researchers inquisitive from the old times. This has resulted in a revolutionary concept of Artificial Intelligence (AI).[2]

There are different contributors in the research history, conceptualization, and evolution of artificial intelligence. History dates back to the Aristotle era when he for the first time presented the concept of artificial intelligence. Though he only proposed a view on the outset of machinery that can substitute human thought processes, his endeavor to acknowledge human thinking as a form of logical system focused on analytic reasoning has been a foundation that computers can fully substitute man's method of thinking.[3]

Later in the 1950s, McCarthy acquainted us with his work on logistic AI through a paper in which he listed non-monotonic logic, practical reasoning and ability, the belief and knowledge, and conceptualizing the context, altogether lay down the analytical facts that can be further reinforced by researchers to solve bigger problems. In 1956, the field of artificial intelligence gained academic recognition and John McCarthy was honored as the father of artificial intelligence.[4]

In 1978,an applied mathematician, named Richard Bellman, described artificial intelligence as the mechanics associated with human activity related to thought process, consisting of basic cognitive process, decision making ability, and problem-solving.[5] It is a field of both engineering and science,associated with the perceptive of intelligent behavior, and creating artifacts that replicate such behavior.[6]"It's basically an area of computer science that focuses on the foundation of machines that work and respond like humans."[7]

Artificial Intelligence cannot be a replacement for the human mind, as the human brain works on perception, interpretation, and reasoning.[8] Although, to a greater extent, it supports human interpretation and actions.[9] There are two categories- "Machine learning" and "Deep learning". In machine learning,the human experts first engineer the data systems and then processed for computing algorithms, while in deep learning, learning and mapping of features are done in a single step, thus making it more resourceful for handling complicated sets of data.[10]

To understand artificial intelligence, knowledge of few of the key aspects is important.

-"Artificial intelligence is termed as a capability of machines that exhibits a form of its own intelligence. The aim here was to develop machines that can learn through data so that they can solve the problems."[6]

Artificial intelligence can be of two forms; weak and strong. In weak artificial intelligence, the use of medical and logical mechanisms might be advantageous to human beings to perform intellectual activities with the help of intelligence neural networks. Strong Artificial Intelligence is a scheme that works similar to human intelligence through the construction of some unnatural software and artificial hardware. Strong artificial intelligence is the capacity of the machine to perform and reproduce human behavior expeditiously i.e., features like communicating, learning, planning, making a judgment, and reasoning ability.[11]

Another key term is the "neural networks, which are a set of fixed algorithms that work on signaling generated through artificial neurons. These networks function similarly to the human brain."[10]

Machine learning, a component of artificial intelligence,depends upon the protocol to generate results that are supported by data sets.A sub-type of machine learning is Representation learning in which the categorization of data is done from the algorithm systems generated by computers. The only difference between Machine Learning and Representation learning is that there is no need for hand-labeled data which is required in machine learning.[12]

Another sub-type is "deep learning, which utilizes varied computational layers through a deep neural network, thus analyzing the input data. The goal is to generate patterns to improve feature detection."[13,14]

2. Application of Artificial Intelligence in Dentistry

2.1 Patient management

In the operatory, "virtual dental assistants can accomplish the tasks with minimal errors and higher accuracy, also less workforce is required. Artificial intelligence software is helpful in the documentation of necessary data more efficiently and comprehensive virtual data can be used later for providing ideal treatment to the patients as and when required. Also, it can be used for managing appointments, insurance, and collecting all required dental records.[15]

In the case of dental emergencies, Tele-assistance can be provided by dental health-care professionals.[16]

2.2 Diagnostic dentistry

Certain conditions with multi-factorial etiology can be efficiently diagnosed using trained neural networks.It can be considered as one of the ideal modalities for diagnosis and treatment planning of the oral soft tissue lesions as it can be used for grouping the doubtful premalignant and malignant changes.[17]Aubreville et al.mentioned about automatic system based on artificial intelligence for diagnosing oral squamous cell carcinoma and stated that this approach was found to outperform in image recognition.[18] Ariji et al.,applied deep learning system for developing computed tomography images for classification and diagnosing lymph node metastasis which showed high diagnostic accuracy, specificity, and sensitivity.[19]

Imaging systems like Computed Tomography Magnetic Resonance Imaging can identify minutest changes at the single elemental levels, which might go unnoted to the human eye. Accurate radiological landmarks can be located using cephalometric diagnosis. Yu et. al. demonstrated the excellent method for orthodontic diagnosis of landmarks with the help of lateral cephalograms, based on his artificial intelligence model of skeletal diagnosing system.[20] Devito et al. worked on model which used bitewing radiographs for diagnosis of the proximal dental caries and proved that this neural network is beneficial for diagnosis.[21]

2.3 Oral and Maxillofacial surgery

The development of "robotic surgery" has been a milestone in the surgical field. Image-guided surgeries can be planned in the cranial area including biopsy, tumor or foreign body removal, oral implant surgery, and mandibular joint surgery.[22]

The most progressive innovation based on artificial intelligence is the application of Bio-printing, where cells are generated in thin layers producing living tissue and organs can be constructed using this technology. This emerging application can be utilized for reconstructing the oral tissues; both hard and soft tissue.[23]Nin˜o-Sandoval et al. used artificial intelligence based model for predicting the morphology of mandible and demonstrated that this framework may be the key for facial reconstruction in later years.[24] Tobel et al. devised a technique for assessing the development of lower third molar. Further he suggested the need for optimization to attain a fully automatic system for estimation of the dental age.[25] Patil et al. used artificial neural networks for gender determination and proved this model to be a great tool for gender prediction and thus, this application can also be used in the field of forensic sciences for promising outcomes. Artificial intelligence has its applications extending to Forensic dentistry.[26]

2.4 Prosthodontics

Use of Rapid Prototyping in prosthodontics.[27] It incorporates computer-aided design, databases and logic, and knowledge-based information. CAD/CAM technique basically helps to create three-dimensional models and aids in the manufacturing of inlays, onlays, and crown and bridges. This technique has greatly reduced the human efforts on time-consuming lab procedures also reducing the errors in final prosthesis.[28]

The computer-guided digital impression is another useful application of artificial intelligence in prosthodontics. They are not only faster and more accurate but also lab procedures are eliminated, greatly reducing the human mistakes. This software also helps in predicting the movement of teeth and the final results after treatment before planning the prosthesis.[27]

In Implantology, this software has contributedin planning surgeries to the minutest details before the actual surgery. However, artificial intelligence has revolutionized the surgical field, and nowadays many ofexpert surgeons are performing semi-automated surgeries using robotics efficiently.[29]

Most of the studies in the literature of using artificial intelligence in oral implant surgery indicated more accuracy than manual placement even when it is performed by well-experienced surgeons. Despite shorter operation time, high intra-operative accuracy has been acknowledged with the help of AI. Image guidance allows careful surgical operation leading to a decrease in the necessity for revision procedures.[30]

2.5 Orthodontics

Designing software has been a great aid to orthodontists to fabricate the best possible aesthetics for patients considering all the variables like measurements of face, anthropological computation, and even the patient's desire. At the same time, making impressions and several laboratory steps can be eliminated. The results are also very accurate when compared to tasks performed by humans. The final treatment outcome and the desired

tooth movement can be foreseen using mathematical algorithms and statistical analysis. Thanathornwong used Bayesian network model wherein, the tooth malocclusion data is fed and the need for orthodontic treatment can be assessed. This model showed promising results.[31]

Aligners can be printed using 3D scans to customize the treatment. A data algorithm coupled with printed aligners is created which provides information regarding the tooth movement, the pressure requires for the desired tooth movement. This conjugation not only provides meticulous treatment; also it lessens the chances of error and reduces the time period required for management.[32]

2.6 Endodontics

Excellent results are demonstrated by the study conducted by Lee et al., wherein artificial intelligence based algorithms were applied for detection of dental caries on periapical radiographs.[33]

Working length can be determined accurately, which is the key to the success of root canal treatment. Saghiri et al. utilized the artificial intelligence based system ofneural network and reported 96% accuracy in working length determination when compared to professional endodontists.[34] Also, minor apical foramen can be located precisely and vertical tooth fractures can be diagnosed using AI as proved byFukuda et al.[35] Study by Hung et al.,reported use of the similar application for diagnosing root caries and showed significant results.[36] Ekert et al., applied neural networks to sight apical lesions and demonstrated excellent results on panoramic dental images.[37]

2.7 Periodontics

Artificial neural networks can be effectively used to categorize the patients into chronic and aggressive periodontal disease, based on their immune response profile.Yauney et al. described this automated system to be useful and effective in correlation of the systemic health to the poor periodontal status.[38] Krois et al.used Deep-convoluted neural networks based system for detection of periodontal bone loss and stated that these technologies can reduce the diagnostic efforts of the dentists.[39]

2.8 In General Dentistry

Due to various upcoming advancements in the field of dentistry with the use of artificial intelligence, such as improvement in the dental equipment and chairs from conventional hydraulic to an electrically operated chairs. The upcoming recent advances includes voice controlled dental chair which requires no or minimal efforts of dentists. It's not of a much time to see in this evolving era, where dental chairs would be able to record patients vitals and would be able to assess anxiety levels of the patient as he/she sits on the chair.[40]

3.Conclusion

The last decade has shown tremendous growth in the field of artificial intelligence. Dentists are not behind in implementing this technology. Thus, in the upcoming days, learning and understanding the ideas and the techniques involved will be clearly advantageous. There is enormous potential for research in Artificial Intelligence in dentistry and medicine integrated with clinical practice would yield improved results.[41]

Applications like image and speech recognition, natural language processing, and neural networking have transformed dentistry in numerous ways.[12] The challenges and drawbacks need to be overcome. Advantages of artificial intelligence in dentistry includes performing work in nearly no time, a logical and executable judgment that leads to accurate diagnosis and these procedures can be standardized. The shortcoming includes; the complexity of the system, costly setups, and lack of adequate training.[42] Another drawback is the "data snooping bias", which results when the data is used for both testing and training. Also, the data used currently is inaccurate and insufficient. Thus, it is the duty of dentists to focus on collection of genuine data that can be used for artificial intelligence in dentistry in near future. Maddox et. al., suggested that the information provided by today's dental artificial intelligence based applications are partial and cannot be relied on completely for complex decision-making.[43] Moreover, questions of transparency remain the same.

This technology has the potency to revolutionize medical health care and, along with it, bring a change in dental medicine as well; and, particularly, research in dentistry, as it has a role to ensure that artificial intelligence will improve dental care, at lower rates for the benefit of patients. This will cause welfare of the patients, dental care providers, and to the society in general. Artificial intelligence can surely be a tool in making significant progress for the delivery of better health-care to the patient, but it cannot replace human knowledge, skills, and power of judgment in any way.[13] In conclusion, artificial intelligence is not a myth but our forthcoming in dental practice. The applications are growing day by day in every area. Nonetheless, a better understanding of the technology and the based concepts will surely benefit in the future.[7]

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