Artificial Intelligence: Precision Dentistry Unleashed

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Access This Article Online

Website:
www.healtalk.in

Quick Response Code:

DOI: https://doi.org/10.5281/zenodo.10682746

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Abstract

Over the past two decades, the field of artificial intelligence (AI) has experienced notable growth and progress. In the fields of medicine and dentistry, AI shows significant potential for improving patient care and revolutionizing healthcare practices. In the dental field, ongoing research delves into various AI applications, including the recognition of normal and abnormal structures, disease diagnosis, and the prediction of treatment outcomes. This appraisal provides an overview of both current and potential utilizations of AI in the realm of dentistry.

Keywords- Artificial intelligence, dentistry, technology.

Introduction

Artificial Intelligence (AI) refers to the capability of machines to perform tasks traditionally requiring human intelligence. While the concept dates back to 1950, it only became a practical tool in the last two decades. The rapid development of AI technology, driven by big data, computational power, and sophisticated algorithms, has significantly impacted various aspects of daily life. In dentistry, AI has been embraced across all disciplines, including operative dentistry, periodontics, orthodontics, oral and maxillofacial surgery, and prosthodontics. Most AI applications in dentistry focus on diagnosis using radiographic or optical images.[1]

When employed in medicine and dentistry, AI presents significant opportunities to enhance patient care and revolutionize the healthcare landscape. In dental universe, ongoing research is exploring diverse applications, including the identification of various structures, disease detection, and the forecasting of treatment outcomes.[2]

What is Artificial Intelligence?

Artificial intelligence involves replicating human mental abilities within a computer system. The ultimate goal is to create a machine capable of emulating or surpassing various aspects of human cognition, such as reasoning, understanding, imagination, perception, recognition, creativity, and emotions. Although achieving this ambitious objective is still a considerable distance away, there have been noteworthy successes in certain aspects of the field. Certainly, more significantly, the exploration of artificial intelligence has not only led to modest accomplishments but has also given rise to a suite of highly beneficial computing tools. These tools have empowered the resolution of challenges once deemed overly complex, facilitating more effective solutions for a broad spectrum of problems. AI tools can be broadly categorized into the following types:

How to cite this article: Kumar V et al.: Artificial Intelligence: Precision Dentistry Unleashed, ***HTAJOCD. 2024; Jan-Feb(3):45-48.***

1. Knowledge-based systems (KBSs), which involve explicit models utilizing words and symbols.
2. Computational intelligence (CI), which employs implicit modeling through numerical techniques, including hybrid approaches.[3]

History of Artificial Intelligence

In 1955, the term AI was initially introduced during a two-month workshop called the Dartmouth Summer Research Project on Artificial Intelligence. This workshop was led by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon. Despite its inception, the concept remained theoretical, and practical constraints hindered researchers from actualizing AI machines in the 1950s.

Between 1957 and 1974, the AI field experienced rapid expansion, driven by the increased availability and accessibility of computer power, along with advancements in AI algorithms. During the 1980s, the development of AI took place along two distinct paths: machine learning (ML) and expert systems. These paths represent opposing approaches in AI theory. Machine learning enables computers to learn through experience, while expert systems, conversely, replicate the decision-making processes of human experts.[4]

Applications in Dentistry

AI in Prosthodontics-

The integration of AI-driven progress has brought about a substantial transformation in the field of prosthodontics. The adoption of digital impression-taking and intraoral scanning techniques has revolutionized the construction of both fixed and removable prostheses, guaranteeing an unprecedented level of precision.

In the field of removable prosthodontics, AI algorithms play a crucial role in analyzing patient data, which includes assessments of oral scans and impressions. This analysis contributes to the creation of more precise and personalized designs, ensuring a superior fit and increased comfort for patients. Additionally, AI aids in the selection of optimal materials and configurations for removable prosthetics, maximizing their durability and aesthetic appeal.

While the development of an AI-powered system in fixed prosthodontics is ongoing, its primary advantage lies in its ability to analyze and extract insights from an extensive database containing millions of doctor-approved crowns. This database continues to expand as new data is regularly added to the cloud. The AI system assesses the construction of each high-performance restoration to determine the most optimal functions, taking into account perfect occlusion, contacts, and margins tailored to individual cases. Through this process, the AI system learns from successful crown designs, continually enhancing its capabilities over time.[7]

AI in Endodontics-

Understanding the different types of roots and root canal systems is crucial for the success of nonsurgical root canal therapy. Cone-beam computed tomography (CBCT) imaging and periapical radiography are commonly used for this purpose. Compared to radiography, CBCT imaging has shown higher precision in evaluating the shapes of both roots and root canals.[8] Precisely establishing the working length (WL) is essential for ensuring the success of root canal treatment. Several techniques are utilized to assess the working length, including radiography, digital tactile sense, electronic apex locators, patient feedback based on the insertion of a paper point or file point into the root canal system, and cone-beam computed tomography (CBCT) imaging. Among these, dental practitioners commonly use radiography and electronic apex locators as standard methods. In digital radiography, the clarity of the image plays a crucial role in accurately interpreting the root canal system's anatomy.[8]

AI in Implantology-

In implantology, AI plays a crucial role beginning with computer-assisted planning. Algorithms analyze patient-specific data, including radiographs and medical history, to recommend optimal implant locations, sizes, and angles. AI-powered image analysis is also utilized to evaluate bone quality and quantity for implant placement. Through accurate analysis of radiographic images, AI assists in identifying potential anatomical limitations, aiding clinicians in making informed decisions about implant surgical techniques.[9]

A noteworthy advancement is the incorporation of AI into robotic surgery. AI-powered robots offer real-time guidance during implant procedures, ensuring the precise execution of the preoperative plan. This diminishes the likelihood of errors, resulting in safer surgeries and improved patient outcomes.[10]

AI in Orthodontics-

Cephalometric analysis, specifically the identification of landmarks on lateral cephalograms, plays a pivotal role in orthodontic diagnosis, treatment planning, and evaluating treatment outcomes. The traditional manual landmarking process is time-intensive, dependent on experience, and can exhibit variations both within and among orthodontists, significantly affecting clinical practices' efficiency and precision. While automated landmark detection was explored as early as the mid-1980s, the initially high error margin hindered practical implementation in clinical settings. In recent years, with the advancements in AI, several studies have utilized cephalometric analysis, with ongoing efforts to improve its reproducibility, efficiency, and accuracy. Effective orthodontic treatment relies on thoughtful decision-making, especially in areas such as planning tooth extractions and evaluating the potential need for surgical interventions. AI is anticipated to play a substantial role in supporting orthodontists, particularly those with limited experience, by assisting in making precise and informed decisions.[11]

AI in Periodontics-

Luciano et al. pioneered a specialized haptics-based dental simulator designed exclusively for Periodontics. This simulator assists students in developing the necessary skills for diagnosing and treating periodontal diseases. Utilizing a haptic device, students can physically perceive 3D representations of upper and lower teeth, as well as the gingiva, offering a tactile learning experience. The haptic feedback generated emulates the clinical sensation experienced by an operator using dental instruments.

Companion et al in 1998 released the first results of an ultrasonographic periodontal probe developed at NASA Langley. The primary objective of this probe was to address the prevalent problems of pain and imprecision associated with manual probing. It incorporates a hollow conical tip filled with water to facilitate the transmission of the ultrasonic beam into the tissues.[12]

In 2017, Rana, Yauney, et al. introduced a machine learning classifier designed to distinguish between inflamed and healthy gums. After being exposed to light ranging from 405 to 450 nm in wavelength, an oral imaging device captured the fluorescence emitted by the biomarker porphyrin. Plaque manifested in yellow and orange hues, while inflamed gums were depicted in shades of magenta and red. The classifier then produces a pixel-by-pixel segmentation, pinpointing areas suspected to be impacted by gingivitis.[13]

AI in Oral and Maxillofacial Surgery-

AI has made significant strides in the realm of robotic surgery, particularly within Oral and Maxillofacial Surgery (OMFS). Cranial surgical interventions, including procedures like dental implants, tumor resection, biopsies, and temporomandibular joint surgery, have demonstrated successful outcomes with the assistance of AI. Research suggests that surgery augmented by AI has improved the precision and safety of oral implant procedures compared to conventional freehand methods. Notably, the integration of AI has resulted in a decreased requirement for revision surgeries and implant repositioning in specific cases. Furthermore, AI-assisted approaches have facilitated more accurate surgical resection of tumors and cysts, thereby reducing the necessity for additional procedures.[14]

The application of computer-aided planning, relying on 3D imaging, streamlines tasks such as cephalometric analysis, splint production, and operation simulation. This technology provides a more lucid visualization of dental irregularities, encompassing aspects like yaw rotations, occlusal plane canting, and variations in the length of the mandible's body/ramus. The integration of virtual surgical planning, facilitated by advancements in 3D imaging and 3D printing, enhances surgeons' understanding of anatomical structures, leading to significantly improved treatment outcomes. The potential for AI to contribute to the planning of orthognathic surgery is considerable, complementing the existing methodologies of 3D imaging and 3D printing.[14]

Conclusion

Although numerous studies have highlighted potential applications of AI in dentistry, these systems are far from having the capacity to substitute dental professionals. Instead, the use of AI should be viewed as an adjunctive tool to aid dentists and specialists. It is crucial to ensure the secure and regulated integration of AI, emphasizing that humans maintain the capability to guide treatment and make informed decisions in the field of dentistry.

Successfully incorporating AI into dentistry necessitates training in dental practices and continuous education—a challenge that many institutions are currently ill-prepared to address. Additionally, AI plays a crucial role in virtual reality (VR) and augmented reality (AR). The emerging concept of mixed reality integrates elements of generative AI, VR, and AR, incorporating computer-superimposed information overlays to enhance learning and surgical planning. With diverse AI systems under development for various dental disciplines and demonstrating promising initial results, the potential of AI in the healthcare system, particularly in oral health, should not be underestimated. AI systems hold the promise of serving as valuable tools for oral health professionals.[2]

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