

AI IN DENTISTRY- PROMISE OR PARADOX

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Abstract

AI - Artificial Intelligence is one of the most important contributions of the fourth Industrial Revolution. It is blossoming and expanding rapidly in all sectors.¹ It can learn from human expertise and undertake works typically requiring human intelligence has emerged as a transformative technology in various industries and has potential in dentistry, which is gaining significant attention. The benefits of this technique are better efficiency, accuracy, and time saving during the diagnosis and treatment planning. In dental practice, I envision AI not as a replacement for dental professionals but as an adjunctive tool that fortifies the dental profession. While AI heralds improvements in diagnostics treatment planning and personalized care, ethical and practical considerations must be meticulously navigated to ensure the responsible development of AI in dentistry.² On the dark side of it, AI systems trained on limited or non diverse datasets may produce biased results. It may not always capture the nuance of complex dental cases where human judgment, intuition, and experience are critical. AI in dentistry often involves the collection and analysis of sensitive patient data such as X-rays and treatment records and if these systems are not secure, they could be vulnerable to data breaches. If an AI system in dentistry makes a mistake it is difficult to assign legal responsibility, should the blame fall on the developer, dentistry, or the institution.

This is why ethical frameworks are necessary to ensure patient safety, protect privacy, and promote fairness and equality therefore organizations like HIPPA have set high standards for patient data protection. In conclusion, AI offers transformative potential to revolutionize the field, from improving diagnostic accuracy to enhancing operational efficiency and patient care. The paradox lies in balancing the promise of innovation with the challenges of ensuring safety, equity, and the preservation of the dentist-patient relationship.³

Keywords: Artificial intelligence, Dentistry, Treatment Planning, Dental Ethics.

Introduction

The fourth Industrial Revolution is opening a new era, one of the most important contributions of which is AI. It has emerged as a transformative technology and is blossoming and expanding rapidly in all sector.⁴ Artificial Intelligence (AI) in dentistry presents a compelling intersection of promise and paradox. AI offers transformative potential to enhance diagnostic accuracy, optimize treatment plans, and improve patient outcomes. While AI has the potential to act as a powerful ally in dentistry, it is crucial to navigate its complexities, ensuring that the integrity of the practice is maintained. The fourth Industrial Revolution is opening a new era, one of the most important contributions of which is AI. It has emerged as a transformative technology and is blossoming and expanding rapidly in all sectors.

Many studies on AI applications in dentistry are underway or have been put into practice in the aspects

such as diagnosis, decision-making, treatment planning, prediction of treatment outcome, and disease prognosis. Many reviews regarding dental AI have been published, while this review aims to narrate the development of AI from incipient stages to present, describe the classifications of AI, summarise the current advances of AI research in dentistry, and discuss the relationship between Evidence-based dentistry (EBD) and AI. Limitations of the current AI development in dentistry are also discussed.

Artificial intelligence

Artificial intelligence, a major invention that imitates human cognitive capabilities, has captured the attention of scientists all around the world. The core component of artificial intelligence technology is a neural network that is designed like the human brain can also simulate human thought. Strongly interconnected neurons make up this type of brain architecture, which primarily

functions as a data processing system to address a particular issue. It is a rapidly evolving technology that allows robots to carry out formerly human-only jobs. Recently it has started to be used in dentistry, which has resulted in exceptional achievements. AI is an efficient method for analyzing clinical dental data. AI developments hint at potential advantages for health care, including fewer postoperative complications, higher quality of life, better decision-making, and far fewer needless procedures. Knowledge of the fundamental components of current artificial intelligence systems in use in society is crucial for having a thorough understanding of AI. It demonstrates its intellect through the resolution of issues using data. Machine learning: methods used to predict results from a dataset. Making it easier for machines to acquire data already available and resolve problems without human intervention is the goal. Neural networks: use artificial neurons and compute signals that execute similarly to those of the human brain.

Deep learning has numerous computational layers that create a network of neurons that identifies patterns on its own, thereby improving detection. Data science: a process of analysis of data and extraction of information from the analysed data. Big data analyses a huge amount of data that is steadily expanding in the right direction over the years to give consumers correct information.

Evolution of AI in Dentistry

Dentistry has witnessed significant technological transformations. From the advent of X-rays to digital impressions, each innovation has paved the way for more precise and efficient patient care. Today, we stand at the cusp of another monumental shift with the integration of AI.⁵

The promise of AI in Dentistry

- Enhanced Diagnostics
- AI can analyze dental X-rays and 3D scans to detect cavities, periodontal disease, tumours, and other abnormalities with high accuracy, often spotting issues earlier than the human eye.
- Personalized Treatment Planning
- AI systems can recommend customized treatment plans based on a patient's medical history, imaging

data, and predictive outcomes, improving precision and efficiency.⁶

- Routine administrative tasks like appointment scheduling, billing, and patient record management can be automated with AI, freeing up time for dental professionals to focus on patient care.
- Teledentistry and Remote Monitoring
- AI supports remote dental consultations by analyzing patient-uploaded images or data, enabling early intervention and broader access to care in underserved areas.⁷

AI in Diagnosis & Imaging

- AI-Powered Radiograph Analysis: AI-powered imaging tools can identify dental caries, periodontal diseases, and oral cancers with up to 90% accuracy, compared to the average 40% accuracy of conventional X-rays.⁸
- Early Detection Algorithms: Early detection algorithms assist in identifying anomalies, enabling timely intervention and improved patient outcomes.⁹
- AI-based Radiographs Analysis cost less than 5% of the radiograph cost.

AI-Powered Dental Robotics & Surgeries

AI-driven 3D imaging software with a robotic arm designed to perform dental procedures. The proprietary system aims to complete tasks such as crown placements in just 15 minutes. Beyond diagnostics and planning, AI extends into the realm of surgical procedures. AI-guided robotic systems have demonstrated high precision in implant placement, reducing the margin of error significantly and improving patient outcomes. Robotic-assisted procedures reduced errors by 20% and decreased operation times by 15%, according to clinical studies, enhancing surgical precision and patient outcomes.¹⁰

Nanorobots: Nanotechnology-based dental nanorobots can be utilized for tooth repair, local drug delivery, dentin hypersensitivity, single-visit orthodontic realignment, endodontic and conservative dentistry, cavity preparation and restoration, local anesthetic, and dental robotics. The nanoscopic dental robots offer quick and accurate care

Endo micro robots: They were created to enhance endodontic treatment's precision and effectiveness and provide top-notch root canal therapy. The endo micro robot accomplishes autonomous drilling, cleaning, shape, and three-dimensional filling of the root canal system with the aid of cutting-edge computer-assisted endodontic technology through online supervision and an intelligent system. It gives precise treatment with error-free outcomes, causing the dentist less discomfort and anxiety. Micro position and orientation adjustment equipment, a travel distance controller, microsensors, an automatic feed rate, and apex sensors with flexible drill and vacuum attachments are all components of an endo-micro robot.¹¹

Robotic dental drill: In this, a very fine needle is used to pierce the gum to find a site of the alveolar bone in a patient with a restrained jaw.

Tooth cleaning robots: Several in vitro results revealed the capability of the robotic system to exhibit reproducibly significant differences in the cleaning efficacies of powered toothbrushes.

Tooth-crown preparation robots: LaserBot, a microrobot is a robotic device that achieves the precise three-dimensional (3D) motion control of a femtosecond laser beam in tooth-crown preparation. Some of the researchers conducted experiments on wax, resin, and teeth by using a system that combines robotic and laser technology to achieve automatic 3D tooth ablation and the results proved that the robotic system could meet the requirements for dental crown preparation.

Orthodontic arch wire bending robots: This robotic technology is also used for bending orthodontic archwires. SureSmileArchWire bending robot is known for bending archwires. Similarly, "LAMDA (Lingual Archwire Manufacturing and Design Aid)" contains a heater that can raise the temperature of a nickel-titanium archwire to 600 °F and bend it within 6 min. Gilbert did a study in which, he did the blind evaluation of the archwires which were manually bent by 15 lingual orthodontic specialists, and the archwires bent by the LAMDA system. The results showed that the LAMDA system had a higher score than the archwire bent by 15 lingual orthodontic specialists.

Robotic articulator: It uses a precise six-axis micro-positioning stage to reproduce the patient's functional mandibular movement with six Degrees of freedom. Using this type of articulator system, a full veneer crown restoration is made up without the need for intraoral occlusal adjustments. However, further research is needed to evaluate this technique.

AI in oral and maxillofacial pathology

AI has been researched mostly for tumour and cancer detection based on radiographic, microscopic and ultrasonographic images. In addition, AI can be used to detect abnormal sites on radiographs, such as nerves in the oral cavity, interdigitated tongue muscles, and parotid and salivary glands. CNN (a type of deep learning model) algorithms were demonstrated to be a suitable tool for the automatically detecting cancer. It is worth mentioning that AI also plays a role in managing cleft lip and palate in risk prediction, diagnosis, pre-surgical orthopaedics, speech assessment, and surgery.²

AI in operative dentistry

Traditionally, dentists diagnose caries by visual and tactile examination or by radiographic examination according to a detailed criterion. However, detecting early-stage lesions is challenging when deep fissures, tight interproximal contacts, and secondary lesions are present. Eventually, many lesions are detected only in the advanced stages of dental caries, leading to a more complicated treatment, i.e., dental crown, root canal therapy, or even an implant. Although dental radiography (whether panoramic, periapical, or bitewing views) and explorer (or dental probe) have been widely used and regarded as highly reliable diagnostic tools detecting dental caries, much of the screening and final diagnosis tends to rely on dentists' experience. In operative dentistry, there has been research on the detection of dental caries, vertical root fractures, apical lesions, pulp space volumetric assessment, and evaluation of tooth wear. In a two-dimensional (2D) radiograph, each pixel of the grayscale image has an intensity, i.e., brightness, which represents the density of the object. By learning from the above-mentioned characteristics, an AI algorithm can learn the pattern and give predictions to segment the tooth, detect caries, etc. For example, Lee et al. developed a CNN algorithm

to detect dental caries on periapical radiographs. They proposed a CNN algorithm to detect caries on intraoral images. compared the cost-effectiveness of AI for proximal caries detection with dentists' diagnosis; the results showed that AI was more effective and less costly.

AI in periodontics

In periodontics, AI has been utilised to diagnose periodontitis and classify plausible periodontal disease types. In addition, it adopted CNN in the detection of periodontal bone loss (PBL) on panoramic radiographs and evaluated the potential usefulness and accuracy of a proposed CNN algorithm to detect periodontally compromised teeth automatically. AI claimed that periodontal conditions could be examined by a CNN algorithm developed by their research group using systemic health-related data

Summary of dental applications of artificial intelligence
AI technologies can help professionals provide their patients with high-quality dental treatment. Dentists may employ AI systems as a supplemental tool to improve the precision of diagnosis, treatment planning, and treatment result prediction. Deep-learning technologies can provide diagnostic assistance to general dentists. Automated technology can speed up clinical processes and boost physician productivity (e.g., automatic completion of electronic dental records by identifying the tooth and numbering). The accuracy of the diagnosis can be increased by using these systems for secondary views

Ethical & Practical Challenges

AI in dentistry raises ethical and practical challenges, including patient data privacy, algorithmic bias, and lack of transparency. Over-reliance on AI may reduce clinical judgment. Inconsistent regulation, high costs, and integration difficulties also pose concerns. Ensuring informed consent and equitable access remains critical for responsible AI implementation in dental care.¹² Despite the promising results of the presented AI models, it is still necessary to verify their generalizability and reliability using appropriate external data obtained from freshly enlisted patients or accumulated from other dental facilities. Future aims of AI research in the dentistry sector include not only raising the performance of AI models to expert levels but also

detecting early lesions that are invisible to the human eye. Mechanical improvements in clinical/dental applications are very costly for the doctor and the patient too. Most common and repetitive procedures like scaling, curettage, restoration, and bonding of orthodontic wires in the oral cavity lack the application of robotic technology. For repetitive and smaller tasks using robots becomes very costly for the patient. According to various research, the reliability and quality of data which is received from various sensors and digital healthcare devices are not very clear. The Datasets in medicine are still imperfect and that was happening due to documentation error or incomplete data error. So, it is very difficult to develop an error-free machine learning AI robotic model. Using robots in dentistry somehow leads to unemployment just like robots did in the industrial sector. The number of staff working for a doctor will reduce leading to displacement in the job. The trust relationship between patients and medical professionals always should be on good terms, but adding AI into the picture will likely impact the trust of the patient first. We all know AI robotics are performing well in these initial stages of experiment but, doctor surveillance is still important. AI Robots operate logically, but healthcare professionals do not. If doctors become intelligent users of AI robots, they may hold the trust relationship between patients and doctors but many patients, who have a limited understanding of modern-day technologies, may face great difficulty in trusting AI robots.

Impact of artificial intelligence on dentists

Although there is plenty of talk about how AI can change dentistry, questions remain about whether it will ever completely replace dentists. Dentistry performed by machines and without human interaction does not represent clinical care. Machines cannot provide clinical intuition, intangible perception, or empathy, which are essential to providing individualised healthcare and professionalism. The most fascinating aspect of human-to-human communication cannot be easily translated into computer language

Future of AI in dentistry

Regenerative Dentistry: AI could play a role in

developing bioengineered teeth and tissues, opening new avenues in restorative dental treatments.¹³

Caries Risk Prediction: AI models are being developed to predict caries risk with high accuracy, allowing for preventive measures tailored to individual patients.

Teledentistry: AI-driven platforms may enhance remote diagnostics and consultations, making dental care more accessible, especially in underserved areas.¹⁴

Conclusion

AI holds significant promise in revolutionizing dentistry. Ongoing research and ethical considerations are crucial to ensure safe and effective integration into clinical practice. A balanced approach is essential to harness AI's benefits while addressing its challenges. Issues such as data privacy, algorithmic bias, and the need for rigorous validation of AI tools must be addressed to ensure safe and effective integration into clinical practice. By complementing and, at times, alleviating them, AI should be viewed as an augmentation tool to assist dentists in carrying out more useful tasks, such as integrating patient information and strengthening professional relationships. Contemporary artificial intelligence excels at using structured knowledge and gleaning understanding from vast amounts of data. But it is unable to create associations as the human brain does, and it is only partially capable of making complicated decisions in a clinical situation. In unclear situations, specifically, higher-level comprehension that depends on dentists' experience is necessary to conduct physical examinations, include medical histories, evaluate aesthetic results, and promote conversation. It's critical to stress that good patient-dentist communication requires a nonverbal assessment of the patient's hopes, anxieties, and expectations. This is true despite the contentious debates surrounding the inclusion of empathy into algorithms for affective robots to convey artificial emotions. These communication pathways are intuitive and unplanned.¹⁵

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