Episode 85 – Artificial Intelligence in Oral Healthcare May 26, 2023

Introduction

Artificial intelligence (AI) has experienced remarkable growth and development over the past two decades. AI is impacting both personal and professional lives in numerous ways, including smart homes, chatbots, self-driving vehicles, and targeted advertisements in social media.

AI is performing healthcare tasks traditionally carried out by humans, and AI applications in healthcare, including oral healthcare, are expanding. AI-enhanced processes could potentially improve diagnosis, treatment, and workflow efficiencies, allowing more timely treatment to improve client care. [1]

AI in medical and oral healthcare has captured attention of researchers because of its multiple applications. For example, researchers developed an AI tool with the potential to predict signs of Parkinson's from blood samples up to 15 years before symptom onset. Other scientists are harnessing the power of AI to identify likely causes of Alzheimer's disease and potential drug targets. [2] [3] [4] [5]

Along with its possibilities, the use of AI in healthcare has its share of controversies, including concerns about ethics, errors, and client privacy. AI is also raising concerns of dishonesty in academia, such as cheating on exams and plagiarism in writing assignments. For example, research shows AI, such as ChatGPT, can pass board certification exams. While plagiarism detection software claims the ability to detect AI-derived text, others warn AI detectors have high error rates. Academic institutes will have to determine how faculty and students will accommodate these new technologies. Thus, reaping the benefits of AI requires balancing its risks. [6] [7] [8] [9] [10] [11] [12]

On May 16, 2023, the World Health Organization (WHO) called for caution in using AI generated large language models (LLMs), such as ChatGPT, to protect and promote human well-being, safety, and autonomy, and preserve public health. WHO stated its enthusiasm about the potential of AI but also has concerns over how it will be used to improve access to health information; as a decision-support tool; and to improve diagnostic care.

WHO is concerned that caution, normally exercised for any new technology, is not being exercised consistently with LLMs. This includes widespread adherence to transparency, inclusion, public engagement, expert supervision, and rigorous evaluation.

Hasty adoption of untested systems could lead to healthcare worker errors, client harm, and erode trust in AI thereby undermining or delaying potential long-term benefits and uses of AI technologies globally. Additionally, data used to train AI may be biased and generate misleading or inaccurate information and the models can be misused to generate disinformation. WHO proposes these concerns be addressed, and clear evidence of benefit be measured before widespread use in routine healthcare. [13]

Terms and definitions

Developments in AI began in 1943. The term artificial intelligence was coined in 1956. AI refers to development of machines able to perform tasks previously requiring human involvement. [14]

AI utilizes algorithms extensively and AI systems are designed to mimic human intelligence. Approaches to AI systems include machine learning, deep learning, cognitive computing, computer vision, natural language processing, and large language models, among others. [15]

Artificial intelligence (AI) are computer systems able to perform tasks normally requiring human intelligence (e.g., visual perception, speech recognition, decision-making, language translation). AI leverages computers and machines to mimic problem-solving and decision-making capabilities of the human mind. [16] [17]

Augmented intelligence (AuI), also called intelligence amplification, plays a similar role to AI except rather than AI performing a task for the clinician, AuI assists the clinician in the task, keeping human intelligence elements in the procedure. AuI enhances human intelligence rather than replacing it. [15]

Machine learning is a branch of AI focusing on the use of data and algorithms to imitate the way humans learn, gradually improving its accuracy. It involves training computer systems to look for hidden patterns in data to build analytical models. It enables computers to “self-learn” from training data and improve over time, without being explicitly programmed. [18] [19] [20]

Deep learning is a branch of machine learning based on learning data representations rather than performing task-specific algorithms. Deep learning uses complex neural networks of computing systems that loosely mimic the human brain to discover and analyze complicated patterns in very large databases. [15] [21]

Cognitive computing uses computer systems to simulate human thought processes. [15]

Computer vision uses deep learning to recognize patterns in images and videos. Computer vision uses digital systems that can process, analyze, and interpret images (e.g., radiographs). [15]

Natural language processing (NLP) uses AI to recognize speech and written language and communicate with system users in ordinary language. NLP focuses on enabling computers to interpret human language. [19]

Large language models (LLMs) are a type of machine learning model that can perform a variety of natural language processing tasks, including generating and classifying text, answering questions in a conversational manner, and translating text from one language to another. LLMs include some of the most rapidly expanding platforms, such as ChatGPT, Bard, and Bert, that imitate understanding, processing, and producing human communication. [13] [22]

Artificial neural networks (ANNs), also known as neural networks or simulated neural networks (SNNs), are one of the main tools used in machine learning. ANNs try to emulate the human brain, combining computer science and statistics to solve common problems. ANNs are used to find patterns within data and then teach the machine to recognize those patterns. ANNs rely on training data to learn and improve their accuracy over time. [23] [24]

Convolutional neural networks (CNNs) are used for analyzing visual images and image diagnostics. CNNs mimic human neurons, creating a network organized in layers that transfer complex input of data (e.g., images, radiographs) into output data (e.g., diagnosis, planning). [23] [25]

AI in healthcare

AI use in healthcare is wide ranging, including AI-assisted robotic surgery, medical imaging, administrative tasks, and wearable technology. It is projected the global market for AI in healthcare could grow from $1.3 billion to $10 billion by 2024, representing a 40% annual growth rate. [26]

Tens of millions of people wear an Apple Watch that monitors key health metrics and allows wearers to share data anonymously with researchers. More than 400,000 Apple Watch users participated in a Stanford University study to identify atrial fibrillation through this wearable technology. [27] [28]

AI has the potential to drive scientific breakthroughs; aid in diagnosis, treatment, and management of diseases; accelerate drug development and delivery; control costs; and support health equity. Research out of University of Alberta developed a machine learning model able to detect signs of Alzheimer's using speech traits across different languages. The machine learning model could one day be turned into a simple screening tool anyone with a smartphone could use. [29] [30]

Placido et al. (2023) showed AI improved pancreatic cancer prediction, potentially offering a surveillance method for pancreatic cancer. AI-based screening provides an opportunity to alter the trajectory of pancreatic cancer, an aggressive disease that is hard to diagnose early and treat promptly when chances for success are highest. [31]

Ayers et al. (2023) found ChatGPT outperformed physicians in high-quality, empathetic answers to clients' questions. While AI will not replace physicians, AI models could be integrated into healthcare systems to improve physician responses to questions sent by clients and ease the ever-increasing burden in healthcare. [32]

Public perspectives

A qualitative interview study by Robertson et al. (2023) found 52% of participants would choose a human physician rather than AI for diagnosis and treatment. However, participants trusted medical advice generated by AI more when their physicians expressed support of the new technology, signalling the significance of clinicians in guiding client decision-making. Client resistance to AI diagnosis may impinge uptake and undermine treatment goals, but clinicians can support adoption, where the technology is designed with the client experience in mind and supported by evidence of accuracy. Future research is required to ensure AI benefits are secured in clinical practice. [33] [34]

AI in oral healthcare

Although oral healthcare is behind medical healthcare in AI development and adoption, AI products, research, and development for oral healthcare are substantially growing. For example, AI is increasingly used to support clinical and administrative tasks in oral healthcare. Many products are similar to those developed for other healthcare fields, as they can be adapted more quickly than developing new products. [18]

Significant changes in treatment management and delivery are occurring in oral healthcare due to the expansion of AI capabilities. AI is currently used for purposes such as identifying normal and abnormal structures, diagnosing disease, and predicting treatment outcomes. AI is also used in dental laboratories and dental education. [20]

In March 2017, the US Food and Drug Administration (FDA) cleared the first robotic dental surgery system (Yomi robotic guidance platform) for dental implant procedures. In September 2017, the world's first autonomous dental implant placement system placed two dental implants in a person in China. Even though medical staff were present during the one-hour surgery, they did not play an active role. The robot was built to help deal with China's shortage of qualified dentists. [19] [35] [36] [37]

A systematic review by Khanagar et al. (2021) found AI technologies are widely used in various fields of oral healthcare. AI models have been used to detect and diagnose dental caries, vertical root fractures, apical lesions, salivary gland diseases, maxillary sinusitis, maxillofacial cysts, cervical lymph node metastasis, osteoporosis, cancerous lesions, alveolar bone loss, as well as to predict the need for orthodontic extractions and treatment, cephalometric analysis, and determination of age and sex. The authors concluded the findings indicate AI based automated system performance is excellent and mimic the precision and accuracy of trained specialists. Some of the reviewed studies found these systems outmatched performance and accuracy of dental specialists. Although these outcomes do not make AI technologies better than clinicians, they do establish AI can be considered for clinical applications. [38]

Current AI applications

AI progress in oral healthcare has accelerated at an exponential rate. Current applications include image analysis, robotic-assisted surgery, and power toothbrushes.

Image analysis

Image analysis is an area receiving great attention in oral healthcare. In image analysis, millions of images are fed into a computer and the computer, trained by oral health experts, begins to identify patterns. The more images the computer "sees," the more likely its accuracy will increase. Some platforms colour-code images (e.g., caries, bone loss, restorations, calculus, etc.) to enhance radiographic interpretation. Artificial intelligence may help to make radiographic interpretation more precise, consistent, and objective.

Currently image analysis can detect:

- Caries lesions, possibly even earlier than the human eye, assisting clinicians in identifying dental caries that may not yet be detectable by the clinician. This might lead to earlier nonsurgical interventions preventing the need for future restoration.
- Bone levels and bone loss. Image analysis can identify extent and even speed of change when given a series of images over time for the same individual. This allows visualization of these changes with the client present, which helps with client education, and possibly provides predictive value for periodontal deterioration and risk assessment.
- Tumours, types of tumours, and other diseases with manifestations in the head and neck region. This technology is already being used by pathologists, radiologists, oral surgeons, and others to assist in identifying these pathologies.
- Endodontic problems and cracked roots. [19] [39]

Composite restorations

Dental radiometers use machine learning to analyze a curing light's ability and match it to the composite material being used in a restoration. These devices provide clinicians with the ability to fully cure composite restorations to potentially increase restoration longevity, decrease post-operative sensitivity, and improve client outcomes. [19]

Implant surgery

Guided implant placement via robotic-assisted surgery is already occurring. As mentioned previously, the FDA approved the first system in 2017. Combined with image analysis, robotic-assisted surgery may allow highly precise surgical interventions and implant placement, reduce possible errors, and potentially improve client outcomes. [19]

Orthodontics

Increasingly common uses of AI in orthodontics include digital impressions, cephalometric analysis, appliance design, smile design and visualization, treatment planning, orthognathic surgery evaluation, and treatment progress monitoring. Image analysis of dental radiographs and cone-beam computed tomography (CBCT) is a core feature and an example of machine learning and neural networks. [19]

Education

Several companies offer virtual reality clinical simulation systems that use AI technologies to train students in procedures, such as cavity preparations. Intraoral optical scanners are also used with AI systems to measure various preparations for proper thickness, depth, and orientation. Optical scanners, coupled with AI systems, are

also available for use in oral healthcare practices to determine the adequacy of tooth preparations.

Some dental schools have acquired robotic systems for dental implant surgery. Many dental schools are increasingly emphasizing the value of AI by providing students with exposure and access to training early in their careers. [39]

Client education

Some power toothbrushes use AI to recognize brushing styles and coach users so they can achieve the best results in oral self-care. [39]

Dental laboratories

Many clinicians use various aspects of AI for digital impressions, digital scanning, computer-aided design and construction of crowns, retainers, splints, etc. The equipment dental laboratories are using may be more advanced than systems readily available to oral healthcare offices, mainly because they are aggregating more data and using additional machine learning to enhance quality. [19]

Clinical charting and notes

Periodontal charting via voice activation has been available for over a decade. Voice activation mitigates the risk of infection associated with manual entry. AI-enabled voice recognition and recording software may increase charting accuracy and can capture dictated clinical notes and other practice correspondence. The ability to dictate notes and have the notes accurately and efficiently documented may save time and change workflow for clinicians. [19] [39]

Administrative tasks

AI is being used for administrative tasks. Front office staff can use AI-enabled voice recognition and recording software to dictate insurance claims, client communications, billing notes, etc., possibly increasing efficiency.

AI is also being used in client communications to promote business and retain clients. Machine-learning programs interface with practice management software to track and optimize client appointments. AI can identify and assist in scheduling unfinished treatment. The AI system can contact the client based on their appointment preferences and match them with an available appointment. [19] [39]

Phone call tracking software[1] records and scores client calls, allowing practice owners to track performance of individual team members, discover why clients are not scheduled, and train staff to improve phone conversations. [39] [40]

Forensic dentistry

AI technology has been widely applied in forensic dentistry for identifying bite-marks, predicting mandibular morphology, determining sex, and estimating age. Most of these AI models are based on either ANNs or CNNs. [38]

[1] An example of phone call tracking software includes Patient Prism®, currently available in the US.

Health Canada approval

Several companies have received a Medical Device Establishment License (MDEL) from Health Canada for their AI technologies (see chart below for examples). Many companies are enhancing their products and creating new products with AI.[2]

Companies with Medical Device Establishment License (MDEL)

Product name	Company	AI function
Second Opinion	Pearl Inc.	Uses computer vision to detect various oral pathologies, existing restorations, and natural anatomy in dental radiographs. Analyzes radiographs in real time. Allows clinicians to display, review, add, or reject the system's findings during an appointment. [41] [42]
Overjet	Overjet	Software analyzes dental radiographs in real time to detect caries, calculus, and previous treatment (e.g., restorations, root canals). Quantifies bone loss to help diagnosis periodontal disease. Can review the past 18 months of radiographs and cross-reference with on file treatment plans to identify potentially undiagnosed conditions. [43] [44]
Diagnocat AI	Diagnocat Inc.	Imaging technology identifies over 30 common dental conditions on dental radiographs and CBCT (e.g., caries, calculus, periapical lesions, rare pathologies). [45]
Videa Caries Assist	VideaHealth	Uses AI-powered dental caries detection algorithm to identify dental caries on dental radiographs to potentially improve accuracy for treatment recommendations. [46] [47]

Client perspectives

Kosan et al. (2022) assessed clients' perspectives on AI in oral healthcare, specifically for radiographic caries detection and the impact of AI-based diagnosis on clients' trust. Clients showed a positive attitude towards AI in dentistry. AI-supported diagnostics may potentially assist communicating radiographic findings by increasing clients' ability to recognize caries lesions on dental radiographs. [48]

Future AI applications

Periodontal disease

Chau et al. (2023) found AI could be used to identify specific sites with and without gingival inflammation based on intraoral photographs, with high sensitivity and high specificity on par with visual examination by clinicians. This system may be used for monitoring client plaque control effectiveness. Further investigation and training are required for possible improvements and clinical applications. [49]

Restorations

Researchers at the University of Hong Kong Faculty of Dentistry developed a novel manufacturing method using generative AI to create dental crowns. The method employs an AI algorithm using 3D deep-learning approach to produce personalized

[2] Align Technology, producers of Invisalign clear aligners, has introduced Invisalign Virtual Care AI for remote progress monitoring. [58] OraQ AI is Beta testing a product that uses AI and machine learning to evaluate client risk profile based on general health, sleep profile, caries, periodontal disease, etc. to potentially offer clinicians real-time insights and recommendations. [59] [60]

dental crowns with a high degree of accuracy. The method mimics the morphology and matches the materials required for the biomechanics of natural teeth. Clinical trials for using this generative AI for dental crowns are underway. The team is working on the applicability of this tool in other dental prostheses (e.g., bridges, dentures). [50] [51]

Radiographs

A systematic review and meta-analysis by Sadr et al. (2023) found deep learning showed highly accurate results in detecting periapical radiolucent lesions in dental radiographs compared to expert clinicians. The authors noted most studies had risk of bias and the lack of prospective studies. [52]

Implants

Oh et al. (2023) found osseointegration of dental implants could be predicted to some extent through deep learning using panoramic and periapical radiographs. [53]

A systematic review by Revilla-León et al. (2023) found AI algorithms have the potential to identify dental implants via radiographic images, predict implant success using client risk factors, and optimize dental implant designs. [54]

Telehealth

AI-assisted telehealth is being used extensively in medical healthcare, including virtual assistants, remote electronic A1C monitoring, pulse oximeter monitoring for at-home COVID-19 care, and increased client engagement through standardized questions, in which AI helps aggregate answers and match to potential needs for tests or in-person visits, even suggesting possible diagnoses. These AI-enabled medical processes increase efficiency and improve scheduling. Oral health clinicians may see AI-assisted telehealth in the not-too-distant future as several companies are pursuing similar technologies for oral healthcare. [19]

Education

Suárez et al. (2022) investigated using an AI chatbot to create a virtual client to develop dental students' diagnostic skills. The findings suggest incorporating this technology in dental curricula would be positively valued by students and would ensure their training and adaptation to new technological developments. [55]

Homecare

AI technology developed by a multidisciplinary team at the University of Pennsylvania may soon be able to brush and floss teeth, potentially helping those unable to effectively clean their teeth themselves. The team created microrobots composed of iron oxide nanoparticles that demonstrate both catalytic and magnetic activity. Using a magnetic field, the microrobots can be configured to form either bristle-like structures to sweep dental plaque from broad tooth surfaces or elongated strings to pass interproximally like dental floss. The microrobots also have the potential to produce antimicrobials that kill pathogenic oral bacteria on contact. [56] [57]

Take home messages

- AI is a tool and not a replacement for humans. Clinicians should use AI to augment, not replace, their professional judgment.
- AI systems can be used as an auxiliary tool to increase accuracy of diagnosis, treatment planning, and predicting treatment outcomes, thereby assisting clinicians in providing high-quality oral healthcare.
- As costs for AI tools come down, it is very likely their use will increase in oral healthcare practices. However, before incorporating AI-based technology into routine clinical operations, it is important to consider its cost-effectiveness, dependability, and applicability.
- AI-based technology will continue to streamline oral healthcare, potentially eliminating laborious routine tasks while improving the delivery of care.
- Future AI algorithms will analyze client data, including medical history, lifestyle, and genetics, to predict oral disease risk (e.g., caries, periodontal disease, oral cancer, peri-implant disease) enabling clinicians to create fully personalized prevention plans to reduce risk.

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