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The AI Revolution in Orthodontics: Shaping The Future of Smiles

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Abstract

Artificial intelligence (AI) has emerged as a significant revolutionary force in various fields, including orthodontics. AI-based software can improve operational efficiency, disseminate dental knowledge and best practices, and facilitate information sharing between medical and dental practitioners. These aid in treatment of medically compromised patients. Patients should be informed about how their data is used, including the use of AI-based decision-making. Furthermore, it is especially important if there is a lack of regulatory policy, AI is used to save costs instead of improving patient health, or the dentist has a conflict of interest. This review was envisaged with a view to shed a light on modern perspective of AI based treatment modalities in Orthodontics.

Keywords: Artificial Intelligence, Cephalometrics, Orthodontics.

Introduction

Artificial intelligence (AI) is a subject of computer science that allows machines to mimic human cognitive functions. AI has demonstrated significant potential in solving various tasks during the past decade. AI consists of two major branches: expert systems and machine learning. Machine learning improves capabilities by "learning" from training data, as opposed to knowledge-based expert systems that rely on predetermined rules. Machine learning is a potential AI technology due to its adaptability and generalization, capacity to process vast amounts of data, and availability of open-source methods.[1,2]

The goal of artificial intelligence (AI) technology is to create algorithms that can simulate intelligent human behaviour. To respect the human-technology relationship in clinical practice, AI in medicine and dentistry should complement the work of clinical practitioners to improve diagnosis accuracy, visualize anatomical guidelines during treatment, and predict oral disease occurrence and prognosis through data analysis.[3,4]

AI in dentistry should prioritize improving oral and systemic health while remaining cost-effective. The dentist and patient (or surrogate) must agree on whether using AI-based tools is the best option. Moreover, AI-based solutions can speed up diagnostics and provide dentists with easy access to medical and dental history information, allowing for tailored patient care, particularly for those with complex medical histories.AI technology can improve access to oral and dental health services in resource-limited settings, including applications for detecting oral cancer, periodontitis, and dental caries.[5-7]

AI can minimize costs and resources for oral/dental disease prevention and early detection, making it a sustainable approach. As a result, this review was envisaged with a view to shed some light on artificial intelligence in orthodontics.

Overview of AI

In 1956, John McCarthy developed artificial intelligence, sometimes referred to as machine intelligence, as a branch of applied computer science. It is Artificial intelligence, sometimes known as the "fourth industrial revolution," employs computer technology to replicate human-like critical thinking, decision-making, and intelligent behavior. It follows the machine's basic hierarchy of input, processing, and outputImage data (spectral or radiographic images, pictures), text data (medical or treatment records, experimental parameters), or voice data (handpiece noises) can all be used as input data in dentistry. Once the input data has been analysed, the neural networks provide an output.[8,9]

The goal is to provide AI applications in orthodontics, categorizing them as follows :[10]

1. Diagnosis includes cephalometrics, dental, and facial studies, as well as determining skeletal maturity stage and assessing upper airway blockages.
2. Treatment planning, decision-making for extractions, orthognathic surgery, and predicting outcomes.
3. Clinical practice, including practice guidance, remote care, and clinical documentation.

Natural Intelligence Vs Artificial Intelligence (AI): [10-11]

Sn.	Parameters	Natural Intelligence	Artificial Intelligence
1.	Principle	Combining a variety of cognitive processes is the goal of human intelligence in order to adjust to changing circumstances.	AI aims to develop machines that can behave like people and carry out tasks that would typically be done by people.
2.	Progression	According to the theory of natural intelligence, humans are born with the capacity to reason, think critically, and perform other cognitive tasks.	AI was created by humans and has much greater cognitive abilities than humans.
3.	Performance	People make use of their brain memory, processing speed, and cognitive skills.	AI powered gadgets need to process commands and data in order to work.
4.	Mode Of Operation	When it comes to speed, humans cannot match machines or artificial intelligence.	Compared to individuals, computers are capable of rapid processing of data.
5.	Learning Capability	The foundation of human intelligence was developed through the process of learning from a variety of situations and experiences.	They can only learn things by being exposed to them and practicing them repeatedly; although they fail to develop human like thought process.
6.	Decision Making	Human decision making is many a times influenced by subjective factors that are not only based on data.	AI is impartial when it comes to finalizing any decision.
7.	Precision	When it comes to human insights, there is almost always a chance of human error.	Since, AI is based on a set of guidelines that can be updated, it can consistently produce accurate results.
8.	Modifications	The human mind is able to change its viewpoints in response to the shifting circumstances of its environment. People can remember information as a result, and they also perform well in a variety of activities.	AI requires considerably more time to adjust to unneeded changes.
9.	Flaccidity	Juggling several tasks at once demonstrates that multitasking requires the capacity to use correct judgement.	Only a handful of tasks can be completed by AI.
10.	Inter-Networking	In terms of their capacity for conceptual assimilation, degree of self- awareness, and receptivity to other people's emotions, humans outperform other social animals.	AI is yet to appreciate social enthusiastic skills.

11.	Application	It could be characterized as creative or inventive.	AI fails to be creative and inventive due to lack to thinking that human brain supports.

Significance of AI: To provide high-quality care, dental practitioners using AI must have a thorough understanding of both the best practices and methods to implement them. AI has the potential to transform the labour market, corporate collaborations, and patient participation. AI can improve knowledge sharing by collecting large volumes of data and creating a library of methodologies and practices for comparison with results.

PROS & CONS Associated with AI Implementation In Dental Practice: [12]

PROS	CONS
Digital Consultations	Breach in patient's private data can occur
Superior Diagnostic Accuracy	Famine of human surveillance
Enhanced Personalized Treatment Planning	Requirement of congruous grounding of AI technology
Streamlined presidency of clinics	Risks of Bias
Predictive prognostic maintenance of dental equipment	Continual monitoring required
24/7 assistance to patients by AI powered chatbots and virtual assistants	Ineptitude to manage medical emergencies occurring during any dental procedures

Pilot testing of AI systems in dentistry clinics, supervised by clinicians, is recommended to maximize utilization and build confidence. For instance, an AI-based recommendation system uses cephalometric data to recommend exodontia during orthodontic therapy. Cephalometric landmarks differ between Caucasian and African-American men. If training data does not include data from African-American men, the AI system may provide inappropriate treatment recommendations for this population. Continuous monitoring is essential for detecting system faults. However, it's important to grasp the reasoning behind AI's recommendations. AI systems are transparent enough for external observers to see and comprehend. Lack of transparency reduces trust in AI while also making AI systems more vulnerable to cyber criminals. Increased openness might jeopardize privacy by exposing personal information hidden in data sets.[13,14]

Mastering AI Applications: AI-related extensive training is highly recommended for safe and efficient use of AI in dentistry. Job experience and a specialist or doctoral degree were linked to higher interest and knowledge of artificial intelligence, according to a recent study of senior dental professionals and final-year students at the University of Belgrade's School of Dental Medicine. On the contrary, Belgrade University dentistry community's reluctance to adopt AI can be attributed to a lack of fundamental and continuing education on the issue, as well as a fear of AI replacing dentists, both of which have been previously identified as major factors. The survey found that a lack of regulatory framework can cause worry for both patients and dentists when utilizing AI software, which is natural given potential legal uncertainties.[15]

Currently, AI-based software in dentistry is intended to support clinical decisions rather than replace them entirely, requiring dentist supervision. By the end of 2022, the FDA had approved over 500 AI-enabled medical devices, primarily for radiography. Clinical trials have shown that Vide Health's AI algorithm

outperforms dentists in detecting dental caries and declining rate of incorrect diagnoses by 15%. The Dental Assist software from Overjet expedites dental procedures by automatically calculating bone loss in radiographs. The Pearl's Second Opinion solution helps dentists identify dental cavities and other issues. Automation prejudice occurs when individuals disregard or dismiss AI system guidance, or when clinicians choose to follow a machine's opinion over conflicting data. Over and above that, the WHO considers it challenging to assign responsibility for the use of AI in health care due to its multifaceted nature, involving multiple developers, providers, government agencies, and health institutions. In late 2022, OpenAI launched ChatGPT, a text-generation model that can generate human-like responses based on text input. These instances utilized several AI techniques to operate. Mheissen S, Liu Y, et al compared the performance of ChatGPT and Google Bard AI models in answering common orthodontic inquiries. [16,17]

Google Bard and Chat Generative Pre-Trained Transformer (ChatGPT) were used in a recent study by Daungsupawong H et al. 2024 to assess the comprehensiveness and accuracy of orthodontic inquiry results. The results showed that both artificial intelligence (AI) models were capable of delivering complete and reliable information, with ChatGPT having somewhat higher accuracy scores. In comparison, Google Bard produced responses faster than ChatGPT. Despite this contrast, it was determined that the two models produced equal response lengths. Overall, the data show that while Google Bard delivers faster responses, ChatGPT may be slightly more accurate.[18]

Applications of AI in Orthodontics: [19,20]

For Dental Education: Artificial intelligence (AI) is commonly utilized in dental education to develop situations that simulate clinical treatment on patients, minimizing dangers associated with live patient instruction. As a result, the students' pre-clinical virtual patient feedback has improved significantly. The interactive interphase creates high-quality learning environments by utilizing assessment and optimal comparison tools.

For Dental Analysis: Malocclusion is defined by an abnormality in tooth alignment, occlusion, and/or craniofacial connections. In addition to affecting oral health and dental aesthetics, malocclusion has been linked to detrimental effects on social relationships and psychological well-being, according to numerous research. Orthodontists must have a great deal of clinical experience because clinical orthodontic therapy often requires a lot of time to complete multiple investigations. These workloads have had an impact on the efficiency of clinical orthodontic practice, as well as making orthodontic treatment less accessible to non-specialists due to the need for practical experience. Talaat et al. used intraoral photos to identify malocclusion (more especially, teeth crowding or spacing, abnormal overjet or overbite, and crossbite) using the YOLO algorithm. A remarkable accuracy rate of 99.99% was demonstrated by the results. Similar to this, Ryu et al. evaluated tooth crowding using four CNN algorithms and intraoral imaging as training data; the results indicated that VGG19 had the lowest mean errors in the maxilla (0.84 mm) and mandible (1.06 mm).[21-23]

Additionally, Im et al. suggested a dynamic-graph convolutional neural network (DGCNN) to automate the segmentation of teeth in digital models. This method achieved better accuracy and less computation time than the other two commercially available software programs, Autolign (ver.1.6.2.1) and Ortho Analyzer (ver.1.7.1.3).

In addition, precise tooth segmentation and landmark recognition are essential for automated dental analysis.[24]

For Facial Analysis: When evaluating the asymmetry and proportions of the face, facial pictures are crucial. To our knowledge, automated facial analysis has only been the subject of three published research, all of which used 2D frontal images as training data. Rao et al. automatically landmarked and measured facial pictures using an active shape model technique; nonetheless, the inaccuracy of less than 3 mm was present in just slightly more than half of the landmark measurements. When Yurdakurban et al. compared a machine-learning-based program to researchers for assessing asymmetry and identifying facial midline, the differences in the majority of measurements were not statistically significant. The vertical dimensions of patients were examined by Rousseau et al. using a CNN.[25-27]

Skeletal Maturity Indicators: The identification of a patient's growth spurt is crucial for orthodontic therapy, particularly for those who require functional and orthopedic treatment. Hand-wrist X-rays are widely recognized as the most common and accurate method of determining skeletal age. In recent years, several research have reported using AI and hand-wrist radiographs to estimate bone age. A number of studies have shown that the cervical vertebral maturation (CVM) approach is likewise useful for estimating growth and has a strong correlation with the hand-wrist radiograph method. To avoid needless radiation exposure, hand-wrist X-rays are not utilized commonly in clinical orthodontic practice. Instead, the CVM approach, which assesses the size and shape of the cervical vertebrae using lateral cephalograms, has grown in popularity for predicting skeletal maturation.[28,29]

With a larger sample size and a validation dataset to improve the system, Radwan et al. predicted CVM phases using both the CNN model and the unsupervised learning approach. But the classification network's accuracy was only 0.802. Kök et al. identified CVM phases using seven distinct machine-learning techniques. With an average rank of 2.17 in identifying all CVM stages, the ANN was thought to be the most stable method, despite the fact that the data demonstrated that other algorithms had differing degrees of accuracy in predicting different CVM stage.[30-32]

For Cephalometric Analysis: Cephalometric software tools, such as WEBceph™, AudaxCeph™, Cephio™, CephX™, DentaliQOrtho™, EYES.OF.AI™, and FPT-Software™, may recognize points in radiographs and perform analyses. Cephalometric Landmark Identification Data can anticipate and visualize soft tissue changes after therapy, making it useful in therapeutic settings. Using AI for automatic cephalometric landmark detection could reduce human errors. Huang et al (2019) examined the efficiency and accuracy of cutting-edge deep learning techniques for autonomously identifying cephalometric landmarks from cephalometric radiographs. Studies conducted by Kunz et al and Hwang et al showed excellent accuracy in identifying landmarks. They trained human inspectors with specific artificial intelligence (AI) and deep learning algorithms for automatic identification systems. Using lateral cephalometry and AI models, Yu et al. showed promising results in automatic skeleton classification. The findings of the preceding experiments demonstrate that these methods are a viable choice for repeatedly identifying several cephalometric landmarks. Automatically collecting radiography data reduces the need for human intervention and saves time in research and clinical settings as per Park et al, AI matched human

examiners' accuracy in identifying cephalometric landmarks. According to Moon et al and Hye-Won Hwang et al, AI can accurately recognize many cephalometric landmarks since it consistently finds the same position.[33-37]

Algorithms in Orthodontics: [39-41]

Sn.	Type of Application	Type of AI Algorithm used
1.	Determination of Orthodontic Treatment results	Deep Learning (DL)
2.	Diagnosis of the need for Orthodontic Treatment	Bayesian network
3.	Tooth extraction determination	Artificial Neural Network (ANN)
4.	Cephalometric landmarks tracing	Convolutional Neural Network (CNN)
5.	Tooth landmarks / Axis Detection	Neural networks
6.	Skeletal classification	Convolutional Neural Network (CNN)
7.	Tooth Segmentation	Convolutional Neural Network (CNN)
8.	Tooth & alveolar bone segmentation	Convolutional Neural Network (CNN)

Conclusion

The use of artificial intelligence in health care has transformed diagnostic accuracy and treatment planning. These systems have shown to be quite efficient at doing the tasks for which they were created. Orthodontics is a profession in which clinicians rely heavily on diagnostic tools to make clinical decisions. The AI tool has proven to be effective and useful in helping dentists make more precise diagnoses and clinical decisions. The findings from the many studies included in this systematic review indicate that the accuracy of AI-based systems is quite promising and trustworthy. The constant progress of AI algorithms that support pre-treatment diagnostic processes enables the visualization of results and aids decision making throughout treatment, making orthodontics one of the disciplines most benefited by the advent of AI technology.

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