ARTIFICIAL INTELLIGENCE IN ORTHODONTICS: A SYSTEMATIC REVIEW

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ABSTRACT

Artificial Intelligence (AI) is revolutionizing various medical fields, including orthodontics. Its applications range from diagnosis and treatment planning to predicting treatment outcomes and enhancing patient management. This review highlights the advancements in AI technologies within orthodontics, exploring machine learning, deep learning, and their implications on clinical practice.

INTRODUCTION

The "fourth industrial revolution," often known as artificial intelligence AI, employs computer technology to imitate critical thinking, decision-making, and intelligent behavior that is similar to that of humans.[1] AI is a subfield of computer science concerned with developing computer and program that have the ability to perceive information, reason and ultimately convert that information into intelligence action.[2] John McCarthy originally introduced this field of applied computer science in 1956. It is, at times, called machine intelligence.[3]

It is a major invention that imitates human cognitive capabilities, has captured the attention of scientists all around the world in various sectors. AI in dentistry has started to bloom in recent years. From a dental perspective, applications of AI can be classified into diagnosis, decisionmaking, treatment planning, and prediction of treatment outcomes. [4]

APPLICATIONS OF AI IN ORTHODONTICS

Orthodontist being one of the most recently developed and highly researched specialties in the world shows an affinity towards growing technological advances. Orthodontic treatment

planning is usually based on the experience and preference of the orthodontists. As every patient and orthodontist is unique, the treatment is decided mutually by both sides.[5]

Examination of teeth is one of the most critical and controversial decisions in orthodontic treatment because extraction is irreversible, these decisions are always based on clinical evaluations. Patients photographs dental study models, radiographs and rely upon experience. Wrong decisions can lead to undesirable results like suboptimal aesthetics improper bite functional abnormalities related to mastication and speech and in the worst-case scenario for orthodontist diagnosis and treatment planning poses a significant challenge. For making decision good AI is the best way because AI in technology that utilizes machines to mimic intelligence human behaviour.[5]

1. AI in Diagnosis and Treatment Planning

AI can be used in various orthodontic diagnosis and treatment planning applications, with anatomical landmark detection being the most studied domain. AI algorithms, particularly convolutional neural networks (CNNs), have been effectively utilized for diagnosis of malocclusions , evaluation of clinical imagery (e.g., landmark detection in lateral cephalograms) [6,7], providing decision support (need for orthodontic extraction, need for orthognathic surgery, outcome prediction, and others) and partial relief from routine tasks (documentation, remote follow-ups) (Liu et al. 2023).[8]

These systems significantly reduce the time required for manual tracing and improve accuracy. Additionally, AI can assist in analyzing dental radiographs, 3D scans, and photographs to recommend personalized treatment plans. A Bayesian-based decision support system was developed by Thanathornwong [9] to diagnose the need for orthodontic treatment based on orthodontics-related data as input. Choi et al.[10] proposed an AI model to judge whether surgery is needed using lateral cephalometric radiographs. AI has also been used for these purposes on multiple sources, such as radiographs and full-arch 3D digital optical scans. Cui et al. [11] proposed several AI algorithms to automatically segment teeth on a digital teeth model scanned by a 3D intraoral scanner and CBCT images. In addition to tooth segmentation, they also segmented alveolar bone, the efficiency exceeded the radiologists' work (i.e., 500 times faster). While the interest in advanced data-analytic methods, such as AI and machine learning, is rising in the field of orthodontics, the number of regulatorily approved applications employing AI trails the number of publications. As of July 2023, the US Food and Drug Administration (FDA) had approved 676 AI and machine learning–enabled medical devices, of which just over 1% were related to dentistry: 6 in dental radiology and 1 in orthodontics (CEREC Ortho Software; Dentsply Sirona). However, a multitude of scoping reviews are painting a positive outlook for the use of AI in orthodontics.[12]

2. Estimation of growth and development

Timing is one of the main areas to consider in orthodontic diagnosis and treatment planning. Anthropometric indications such as chronological age, dental age, menarche, voice changes, height gain, and skeletal maturation can be used to determine growth and development (skeletal age) and

radiography are frequently utilized to find signs of skeletal maturation. Now the estimation of age using hand and wrist radiographs involve the application of Machine learning algorithm and AI technologies to automate the age. After the input of a vast database like of race, age, and gender AI systems can evaluate the radiographs with deep learning ability. Results show that the AI systems can evaluate the skeletal maturity with a performance like a radiologist.[13]

3. Extraction demands

Need for space to align the teeth in the presence of severe crowding and in order to remedy the protrusion or conceal the skeletal Class II or Class III issues, the teeth may be repositioned (often by retracting the incisors) are the two main causes for tooth extraction in orthodontics.[13] A decision-making expert system was created by Xie et al.[14] to determine whether extraction is necessary for malocclusion patients between the ages of 11 and 15 years. According to the study, identifying the need for extraction or non-extraction treatment had an accuracy rate of 80%. With an accuracy of 84%, Jung et al. employed the ANN to predict the specific extraction patterns.[16]

4. Predicting Treatment Outcomes

Machine learning models have been trained to predict treatment outcomes such as tooth movement and alignment post-braces or clear aligners. This helps in setting realistic expectations and adjusting treatment plans accordingly. AI can also simulate post-treatment facial aesthetics, providing both orthodontists and patients a preview of expected results. Currently, optical facial recognition has been performed by AI applications and they are also simulate much complex cognitive tasks including analysis and interpretation of facial data. Studies in this field showed that AI systems seemed to be promising tools to build a validated formula for the human perception of facial attractiveness.[17,18]

5. Force system prediction using AI

The applied force and tissue response cause tooth movement and orthopaedic changes, and these force systems have been investigated using static systems for simple springs.

In treatment outcome

Headgear, an orthopaedic appliance which acts by restraining the maxillary growth through extraoral traction. There are three types – high, medium, and low pull headgears. A computer assisted inference model has been developed in order to select a right type of headgear according to the clinical situation and this would help a less experienced orthodontist in decision making to choose a right type of headgear.[13]

Soft tissue outcome

Evaluation of soft tissue profile has been considered as an essential part in orthodontic diagnosis and treatment planning. Hence one must pay attention towards the relationship of nose, lips and chin during the orthodontic treatment. [13] 6. AI in Temporomandibular joint disease

Orthopantomogram; OPG is one of the most common examination methods for assessing bony changes in TMJ and if required CBCT may be used for confirming the diagnosis. But sometimes in the absence of an expert, patient's TMJ arthritis or other bony changes may misread. To eliminate this problem an AI algorithm was developed and trained to read TMJ osteoarthritis on OPGs.[13,19]

7. Enhancing Patient Management

AI-driven software solutions optimize appointment scheduling, monitor patient compliance with orthodontic appliances, and facilitate remote monitoring through teledentistry platforms.[20]

LIMITATIONS OF AI IN ORTHODONTICS

The continuous evolution of AI has brought significant advancements in its application in orthodontics. However, there are still some limitations that may preclude the envisioned application of AI in orthodontics.

Firstly, the scarcity and low generalizability of training data, render the current research less reliable. Secondly, while a considerable amount of the literature has explored the application of AI in orthodontics, it remains challenging to directly compare different studies due to variations in study designs, dataset sizes, and evaluation metrics. Last but not least, overfitting is a common issue in the whole field of AI. This means the model performs excessively well in the training datasets but shows unsatisfactory performance in the testing dataset.[8]

FUTURE PROSPECTS

Currently, AI excels mostly in orthodontics diagnosis, yet it has limited guidance on the treatment process. Orthodontists may encounter various challenges throughout the entire orthodontic treatment, including correcting deep overbites and avoiding bone dehiscence or fenestration.

Hence, using AI to aid in preventing or addressing these issues could also be a potential area for future development. [8]

As clinical data continue to grow and AI computing power improves, there is no doubt that AI will significantly advance the field of orthodontics. While AI shows potential in improving time efficiency and reducing operator variability, the accuracy and reliability have not yet consistently surpassed those of expert clinicians. At all moments, human supervision remains essential. Further advances and optimisations are necessary to strive towards automated patient-specific treatment planning. [21]

CONCLUSION

AI is poised to become an indispensable tool in orthodontics, streamlining workflows, improving diagnostic accuracy, and enhancing patient outcomes. Continued advancements and integration of

AI technologies will undoubtedly transform orthodontic practice, paving the way for more personalized and efficient treatments.

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