ARTIFICIAL INTELLIGENCE IN ORTHODONTIC DIAGNOSIS AND TREATMENT PLANNING-A COMPREHENSIVE REVIEW

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Abstract—**The digital evolution in dentistry has now led to multi-source data collection, including clinical information, remote monitoring, photographs, lateral cephalogram, panoramic x-rays, and three-dimensional (3D) imaging exams such as cone beam computed tomography (CBCT), digital dental models, 3D Photogrammetry. Emerging technologies include cloud based systems and databases, that utilize data science approaches and machine learning methods to perform data management, integration,processing, and visualization.**
Recent years, artificial intelligence technology has been a revolutionary tool in health care system, an increase in application of the technology noted significantly in Orthodontics as well. AI is an outstanding tool to help orthodontists as it can be utilized from the beginning to diagnose till the planning of the treatment.
In this review article, artificial intelligence in orthodontics is discussed in relation to its use to clinical decision making, diagnosis and treatment planning.
*Keywords:***orthodontics; artificial intelligence; deep learning; cephalometric analysis; radiology; CBCT; skeletal age; treatment planning.**

1.INTRODUCTION :

As a fact Human brain is the most complicated and an incredible pattern matching machine in the world. The concept of Turing machine was introduced in 1936 by Alan Turing, in order to simulate human calculation. The theory of computation and the Turing machine concept served as the fundamental building blocks for the creation of artificial intelligence (AI). John McCarthy first used the term "artificial intelligence" in 1956[1,2].
During these 70 years, there have been cycles of significant optimism associated with the development of AI, alternating with periods of failure, reductions in research funding, and pessimism[3]. Malocclusion is considered the world's third most prevalent oral disease, and nearly 30% of the population present with great need of orthodontic treatment [4,5]. Clinical orthodontic practice often requires a significant amount of time to conduct various analyses that necessitate the extensive clinical experience of orthodontists. These workloads have affected the efficiency of clinical orthodontic practice and have also made orthodontic treatment less accessible for non-specialists due to the requirement for clinical experience.
Artificial intelligence (AI) is the ability of a system to simulate a human-like intellect machine that can act logically, think critically, and make the best decisions possible[6].
A series of studies have shown that AI can significantly enhance the efficiency of clinical orthodontic practice [7,8].
The main objectives of this article are as follows: elucidate the principles of AI, outline its applications in the diagnostic process of modern orthodontic practices, and discuss the concerns associated with the implementation of AI algorithms in clinical practice.

2. Artificial Intelligence:

AI, in its broadest sense, refers to the actions taken by non-biological creatures in complicated situations. It is a set of tools for solving issues with its own unique set of principles, and it is not required to replicate how the human brain functions. In the area of AI, research is being done to attain generality that is similar to that of humans[9].
According to how well an AI model can solve problems, it can be categorised as narrow or general. From an algorithmic standpoint, there are two basic types of AI: symbolic AI and machine learning[9].
The current paradigm of AI is machine learning. The fundamental distinction between machine learning and symbolic AI is that the former uses a set of rules created by humans, whilst the latter relies on examples to train its models. Algorithms change from rules on how to approach a problem to rules on how to learn from the data at hand in this fashion[9].

3. CLASSIFICATION OF MACHINE LEARNING (ML) ALGORITHMS:

ML algorithms are categorized depending on the nature of learning and desired outcome of the algorithm:
1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning

1. Supervised learning

The data can be discrete or continuous. The supervised learning uses the data for classification if it is discrete and for prediction if it is continuous. The name supervised learning came because of the known outcome.There are two types of variables; dependent and independent in which set of training data is independent variable and known outcome is dependent and the system confirms or rejects the performance based on the feedback signals. In orthodontics, the most commonly used ML algorithm is supervised learning as it provides clinical decision on orthodontic extractions where the Neural Network learning is built based on clinical examination, orthodontic casts, and radiographic measurements.

2. Unsupervised learning

In this, the data is analysed and classified into groups based on clustering or unsupervised classification. This learning is helpful in organizing the data to get a significant information. Here the data is not labelled, and the final outcome is not known[9]

3. Reinforcement learning

Similar to supervised learning, the only distinction being that the feedback signal rewards the system rather of enhancing it. Here, the system has no prior knowledge of the ambient behaviour, and it learns to improve its performance through repeated exploratory trial and error[10]

4.AI in Orthodontics:

The use of medical imaging methods is essential in dental patient care because they aid in the clinical diagnosis of pathologies related to teeth and their surrounding structures[11-13]

Radiological methods, such as orthopantomograms (OPGs) and cone-beam computed tomography (CBCT), play crucial roles in orthodontic diagnosis, treatment planning, and monitoring[14-16]. However, with the increasing number of radiological examinations being performed[17]there is a need for a comprehensive tool to support the process of radiological diagnosis. In response to this demand, multimodular diagnostic systems based on AI have emerged.

One such AI-based system, developed by Diagnocat Ltd. (San Francisco, CA, USA), utilizes CNNs and provides precise and comprehensive dental diagnostics. The system enables tooth segmentation and enumeration, oral pathology diagnosis (including periapical lesions and caries), and volumetric assessment. Several scientific papers have validated the diagnostic performance of this program, demonstrating its high efficacy and accuracy[18-22]. A study by Orhan et al.[18] reported that the AI system achieved 92.8% accuracy in the detection of peria-pical lesions in CBCT images and showed no statistically significant difference in volumetric measurements compared to manual methods. Similarly, a study evaluating the diagnostic accuracy of the program for periapical lesion detection on peri-apical radiographs (PRs) yielded comparable results [19].

I.Cephalometric Analysis:

Cephalometric analysis, especially landmarking on lateral cephalograms, serves as the foundation of orthodontic diagnosis, treatment planning and treatment outcome assessment. Conventional manual landmarking is time-consuming, experience-dependent and can be inconsistent within and across orthodontists, significantly affecting the efficiency and accuracy of clinical practice[20-23].

In recent years, with the advancement of AI, numerous studies have been conducted using cephalometric analysis, the reproducibility, efficiency, and accuracy of which are continuously being enhanced[19-24]. Digital cephalometric analysis improved the diagnosis by reduction of errors and saving time. Lee et al. assessed the analysis of cephalometric radiographs using deep convolutional neural networks (DCNN for the differential diagnosis of the indications of orthognathic surgery. With this DCNN speed increased and complex calculations could be performed in a shorter time[24].

Leonardia R et al. cited the different approaches investigated by various authors into different groups.

1. Image filtering plus knowledge - based landmark search
   - Easy to implement, better accuracy and proper
   - anatomical knowledge
   - Fail to capture the morphological variability
   - Highly dependent on image quality, intensity level
2. Model - based approaches
   - Invariant to scale, rotation, translation and shape
   - variability
   - Not always precise
   - Sensitive to noise
3. Soft - computing approaches
   - Accommodates shape variability
   - Tolerant to noise
   - Difficult to interpret some.
4. Hybrid approaches[25].

5. ARTIFICIAL INTELIGENCE IN TREATMENT PLANNING:

I.EXTRACTION DECISION MAKING:

The two main causes for tooth extraction in orthodontics are as follows:

1. Need for Space to Align the Teeth in the Presence of Severe Crowding

2. In order to remedy the protrusion or conceal the skeletal Class II or Class III issues, the teeth may be repositioned (often to retract the incisors).

A decision-making expert system (ES) was created by Xie et al. to determine whether extraction is necessary for malocclusion patients between the ages of 11 and 15 years. ANN uses the error backward propagation learning technique to reduce the likelihood of error. According to the study, identifying the need for extraction or non-extraction treatment had an accuracy rate of 80%[26].With an accuracy of 84%, Jung et al. employed the ANN to predict the specific extraction patterns[27]

Kong et al. utilized an artificial neural network – multilayer perceptron to predict treatment plan, determine whether extraction or non - extraction is required, pattern of extraction and anchorage pattern. The results showed accuracy of 94 % for extraction and non - extraction prediction, 84.2 % for pattern of extraction and 92.8 % for anchorage pattern, respectively. The most important features for prediction are crowding, upper arch, ANB and curve of Spee. Thereby concluding that the neural network can be used in providing guidance in treatment for the less experienced orthodontists[28].

I. ORTHOGNATHIC SURGERY DECISION MAKING AND PLANNING:

Despite significant developments in orthodontics and surgery, there is a lack of clearly established criteria for qualifying patients for surgical procedures. This issue becomes particularly problematic in borderline cases, where the orthodontist faces the decision of whether to refer the patient for surgical treatment or camouflage treatment[29-30].

Knoops et al. conducted a study in which they applied a 3D morphable model (3DMM) to automatically diagnose patients, categorize their risk levels, and generate simulations for orthognathic surgery treatment plans[31], This approach achieved a sensitivity of 95.5% and a specificity of 95.2%, with an average accuracy of 1.1 ± 0.3 mm. Additionally, the positive and negative predictive values were 87.5% and 98.3%, respectively[31].

II. Management of impacted canine:

In order to achieve the best orthodontic and periodontal results, impacted canines require extensive therapeutic care. The length of the therapy depends on the difficulty level and how much the canine is displaced from the surrounding teeth. An intermediary stance between statistics and artificial intelligence is taken by the Bayesian Network (BN) [3'2].

Based on the angular and linear measurements, panoramic and lateral cephalometric radiographs are helpful in predicting an impacted maxillary canine. The random forest method had the best degree of accuracy and correctly predicted the canine eruption condition (83%). In cases with unilateral canine impaction, Wang et al. used CBCT and a machine learning technique called Learning-based multisource Integration framework for Segmentation (LINKS) to quantify the variance in the maxilla.

III. 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.

6.CONCLUSION:

In the fields of medicine and dentistry, artificial intelligence (AI) has expanded dramatically and now it has been gaining popularity in the field of orthodontics as a powerful problem-solving tool by assisting in diagnosis, treatment planning and prediction of cephalometric landmarks etc. Efficiency, accuracy, precision, reduced effort,time savings, and better monitoring are all benefits of AI. But AI should be assessed and applied carefully in order to avoid any misleading information. Though, AI is heading towards success still it cannot replace an expert clinician in near future.

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