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Review Article

Artificial intelligence in orthodontics: A way towards modernization

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ABSTRACT

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. Along with speeding up the diagnosis and treatment processes, automation can cut labour expenses to zero.

A well-trained AI model, which simulates human intelligence through machines, can aid in all kinds of linear, angular, and volumetric measurements in addition to helping identify landmarks, greatly reducing measurement time so that researchers can focus their efforts on discovering novel clinical insights. In this review article, artificial intelligence in orthodontics is discussed in relation to its use to clinical decision-making, diagnosis and treatment planning, estimation of growth and development, evaluating the facial proportion, prediction of cephalometric land mark and force system and also in analysing the soft tissue treatment outcomes.

1. Introduction

The practice of dentistry has undergone significant transformation in recent years. It has become possible to create more recent technologies that imitate the way the human brain works.[1]

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.[2,3]

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.[4] Deep learning (DL), convolutional neural networks (CNNs), machine learning (ML), artificial neural networks (ANNs), and biological and medical diagnostics are just a few of the disciplines where AI has been employed.[1]

AI has been grown remarkably in the field of dentistry as well and now in one of the most leading branch orthodontics. Studies have shown that AI can be a potent tool for clinical care decision-making in dentistry. AI is now being used for diagnostic imaging. Currently, it is concentrating on a variety of topics, including the diagnosis of osteoporosis, categorization and segmentation of maxillofacial cysts and tumours, a description of periapical disease, the identification of cephalometric landmarks, etc.[4]

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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.[5]

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.[5]

A group of methods known as symbolic AI are built on designing the algorithm in a way that is understandable to humans. This category served as the benchmark for AI research up until the late 1980s and was popularly referred to as GOFAI, or good old-fashioned AI.If-then sentences are used in symbolic AI techniques such that if a specific condition is met, the associated action must be executed. These systems are only as good as the problem's existing human understanding and our capacity to organise it into an algorithm.

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.[5]

3. Classification of Machine Learning (ML) Algorithms

Based on the type of learning and the intended result of the algorithm, ML algorithms are divided into different categories

1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning

Supervised Learning

Because the result is known, the term "supervised learning" was coined. The presented data might be discrete or continuous, and depending on which it is, it is used for categorization or prediction.

The system selects whether to accept or reject the performance based on the feedback signals and there are two sorts of variables: dependent and independent. The dependent variable is a collection of training data with a known outcome.

The most popular algorithm in orthodontics is supervised learning, which allows for clinical decision-making about orthodontic extractions and bases neural network learning on measurements taken from radiographs, orthodontic casts, and clinical examinations.

3.1. Unsupervised learning

Data is analysed and divided into groups based on clustering or unsupervised categorization. This knowledge aids in the organisation of the data to produce meaningful information. The final result is unknown and the data in this category are not labelled.

3.2. 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.[6]

4. AI in Orthodontics

4.1. Diagnosis and treatment planning

The foundation for a correct and precise orthodontic diagnosis is patient information that has been carefully gathered from a suitable database that includes a comprehensive description of the patient's issues. Written or verbal interview information, clinical examination, and review of patient records, including dental impressions, radiographs, and diagnostic pictures, can all be used to build the orthodontic diagnostic database.

When evaluating patients, clinicians face some time and accuracy challenges. Automation of diagnosis and imaging is crucial to improve evaluation speed and accuracy because patient evaluation and obtaining patient records are labor-intensive tasks.

Orthodontic diagnosis is a difficult undertaking since it necessitates a complete simultaneous evaluation of various facial components from various angles. With the use of digital dentistry tools, patient information can now be gathered on a digital platform and turned into a database that can be utilised for both diagnosis and treatment.

The evaluation burden has been significantly reduced and diagnostic variations have been avoided thanks to automation solutions that use AI and machine learning technology.[7,8]

4.2. 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) 8 and radiography are frequently utilised 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.

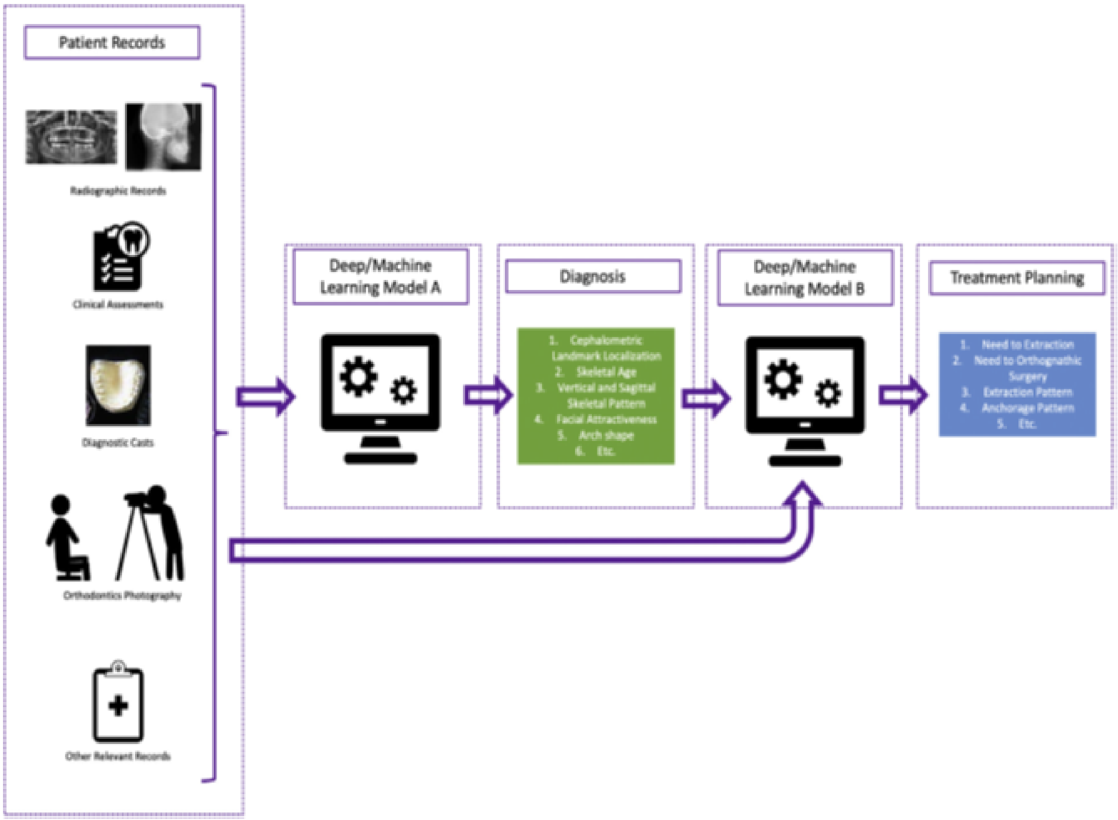

Fig. 1: AI in diagnose and treatment planning [4]

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. [9]

4.3. Cephalometrics

Since many years ago, lateral cephalometric radiograph landmark identification has been crucial in the diagnosis and planning of orthodontic therapy. Automated lateral cephalometric landmark detection was the subject of several investigations.

Currently AI-based cephalogram are replacing manual tracing and identification of land marks by saving time and minimizing errors**.** The AI is largely used to recognise and analyse cephalometric landmarks, make extraction decisions, analyse faces, segment teeth and the mandible, determine bone ages, forecast orthognathic surgery, and segment the temporomandibular joint.

Anatomical landmarks can be automatically recognised on lateral cephalometric radiographs, according to a study by Levy-Mandel et al. (1985) to speed up the cephalometric diagnostic phase. Automated cephalometric tracing was subsequently investigated by a number of other researchers and found to be just as effective as experienced dentists.

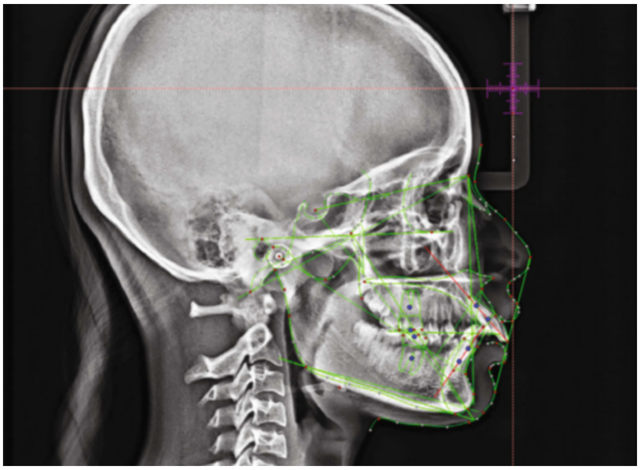

Fig. 2: Prediction of cephalometric landmarks using artificial intelligence. [3]

A deep convolutional neural network-based analysis for automated cephalometric tracing was used by Lee et al. (2020). The programme developed has a high success rate (over 90%), according to the authors, in the differential diagnosis of cephalometric landmarks. [3]

4.4. Facial proportions

Measuring ratios and the linear distances between facial structures are part of the evaluation of facial proportions. Since many years ago, lateral cephalometric radiographs and profile pictures have been used to evaluate the linear measurements, but due to the variations in magnification, sensitive measurements are challenging to make.

Angular measures and ratios can be used to evaluate photographs without regard to dimensions. Currently, surgeons and orthodontists employ measurements of "perfect" face proportions to understand the standards of beauty and replicate aesthetically "beautiful" proportions.[10]

As the facial beauty is a very subjective concept and there is no validated set of rules for facial aesthetics. However, the classical rules of ideal facial aesthetics have some deficiencies in reflecting the beauty perception of the population.[11]

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.[12]

4.5. Extraction demands

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%.[13]

With an accuracy of 84%, Jung et al. employed the ANN to predict the specific extraction patterns.[14]

Li P et al. used ANN to accurately predict the need for anchorage in extraction cases 83% of the time.

To forecast treatment plans, ascertain whether or not extraction is necessary, ascertain the pattern of extraction, and ascertain anchoring, Kong et al. deployed an artificial neural network with a multilayer perceptron. The findings revealed accuracy of 94% for predictions of extraction and non-extraction, 84.2% for patterns of extraction, and 92.8% for patterns of anchoring. Crowding, upper arch, ANB, and Spee's curve are the most crucial characteristics for prediction. Resulting in the conclusion that the neural network can be utilised to guide less experienced orthodontists during treatment.[15]

4.6. 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).[16]

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 multi-source Integration framework for Segmentation (LINKS) to quantify the variance in the maxilla.

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.

An artificial neural network was reportedly employed in a study by Kazem et al. to analyse the force system of T-retraction springs and was successful in input-output mapping.[17]

5.1. In treatment outcome

5.1.1. Head gear

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 by Akgam et al. 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.[18]

5.1.2. 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.

According to a study by Nanda SB et al., a significant change has been noticed on the curvature of upper lip was noted with extraction and non-extraction treatment. Study proved that ANN models are more effective in predicting the changes with extraction and non -extraction cases.[19]

5.2. 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.[20]

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.

7. Conflict of Interest

None.

8. Source of Funding

None.

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