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Artificial intelligence in orthodontics

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***Abstract*---**The clinical use of artificial intelligence technology in orthodontics has increased significantly in recent years. Artificial intelligence can be utilized in almost every part of orthodontic workflow. It is an important decision-making aid as well as being a tool for building more efficient treatment methods. The use of artificial intelligence reduces costs, accelerates the diagnosis and treatment process and reduces or even eliminates the need for manpower. The aim of this articleis to discussArtificial intelligence in orthodontic diagnosis, treatment planning, and predicting the prognosis.

***Keywords*---**artificial intelligence, digital orthodontics, machine learning, treatment planning.

Introduction

Orthodontics deals with the diagnosis of malocclusion and ultimately aims at preventing and correcting them. It is mainly concerned with the craniofacial skeleton, with more emphasis on modifying the dentoalveolar area. An accurate diagnosis and treatment planning are considered as a key to the success of orthodontic treatment, orthodontist needs to be very precise in diagnosing and treatment planning. Digital data processing technologies in medical and dental fields have gained attention in the last two decades. Utilization of digital technology, especially artificial intelligence (AI) technology, can help to reduce the cost and duration of treatment, the need for human expertise and the number of medical error cases.

Artificial intelligence (AI)[1] offers "a way to get sharper prediction from data"[2,3] by simultaneously analysing all the different variables present in a malocclusion. This capacity offers the potential to assist the practitioner to obtain the most favourable outcome when treating a malocclusion.[4]

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Conventional diagnostic procedure

Orthodontic diagnosis is mainly based on the patient's dental and medical history, clinical examination, study models, and cephalometric radiographs which is considered as the most useful tool for orthodontic diagnosis, since it is used to assess the discrepancies related to the dental and the craniofacial skeleton. Studying and diagnosing a malocclusion present many challenges and bring uncertainty to the outcome of treatment due to the large number of variables present in the analysis[5]. The orthodontist must compute mentally all the parameters to recognize patterns based on experience and adopt the most logical or probable approach to solve the problem presented[6,7]. To simplify the analytic process, many orthodontists tend to simplify the analytic process tend to adopt a mechanistical scheme over an in-depth diagnostic approach as it is perceived that experience alone will be enough to assess the probability of success.[5]

This process, called the "feedforward approach,"[8] does not necessarily involve complex feedback mechanisms to improve on previous diagnostics and outcome analyses[3].This principleis explained in [figure.1] as an accepted but potentially inefficient pattern to treat patients. This experience-based approach has been advocated by many clinicians as it is simple but lacks the means to re-evaluate and learn from positive and/or negative outcomes[9].

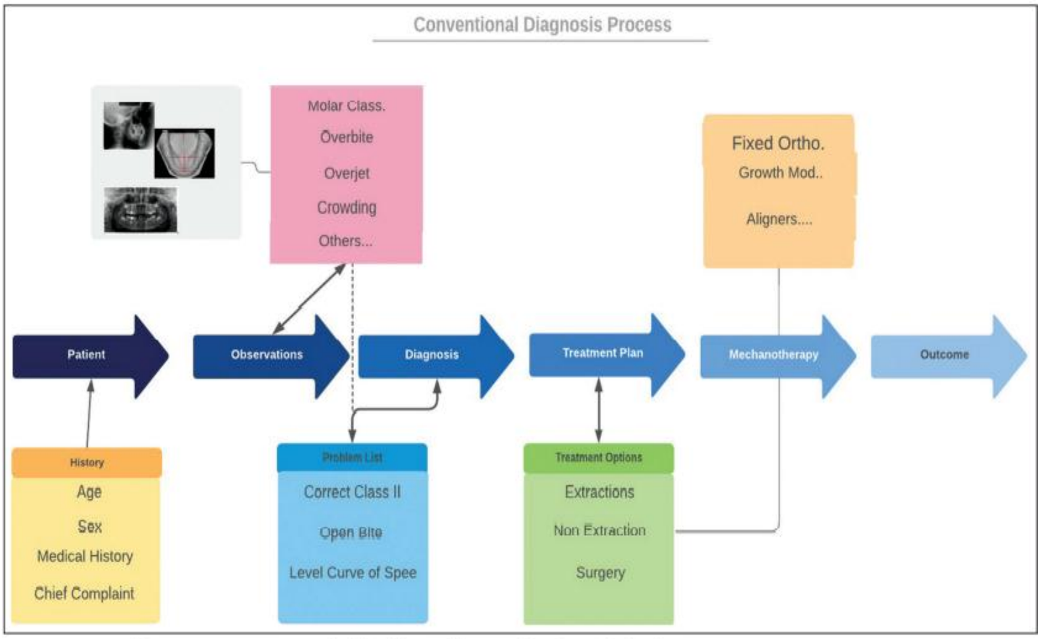

Figure 1: Forward diagnostic process using the "feed forward" approach without feedback.

AI and machine learning

In the beginning, people tried to build hand crafted AI, which means trying to incorporate all the possibilities and its corresponding solutions into computer programs. Under certain circumstances, it works pretty well. Nonetheless, hand crafted AI by no means could really surpass human brain because it literally cannot “learn” anything by itself. Machine learning, briefly speaking, is the process finding a function from given data. The function can later turn new input data such as sounds, images, into valuable output information such as speech recognition and facial recognition.

There are many subfields of AI that have been commonly used in different areas mainly the biological and medical diagnostics, they mainly include machine learning (ML), artificial neural networks (ANNs), convolutional neural networks (CNNs) and deep learning (DL).[10] Data are the key ingredient of machine learning[11] as Modern software programs, sophisticated statistical analyzes, and algorithms require a tremendous amount of data to be able to predict treatment outcomes and analyze the shortcoming of past-approaches. Neural networks use multiple algorithms to attempt to mimic the human brain and based on Bayesian probabilistic graphical models.[12] They require “large datasets to answer queries (questions) regarding a set of standard variables.”[13]

Different algorithms of AI systems were tested in several studies in the orthodontic field. All these algorithms needed a big database of patient examination records as input. The results showed that the use of AI during diagnosis reduced the need for an expert clinician and the number of diagnostic errors. The researchers concluded that the AI applications were promising in orthodontic field.[14,15,16,17,18,19] The state-of-the-art machine learning method ‘deep learning’ is based on artificial neural network (ANN) (Figure 2). ANN was inspired by biological neural network which help us to sense the world and learn from it. The basic unit of ANN is called an artificial neuron.

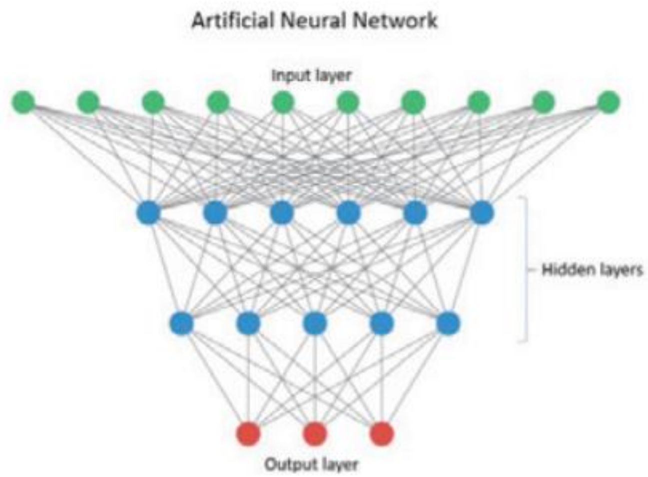

Figure 2. *Artificial neural network (ANN) consist of input layer, output layer and hidden layers in between. Artificial neurons in different layers were connected. Each connection was assigned with a weight representing its relative importance.*

AI in different field

Automated cephalometric tracing

Convolutional neural network (CNN) is a kind of deep learning neural network. It showed outstanding performance in image recognition and classification[20]. Within convolutional layer, multiple filters extract different patterns in the image and come up with multiple feature maps. Followed by pooling process which streamline the size of the image and reducing the computation. After iterative convolutional and pooling process, the output was connected with fully connected layers to classify the image. Medical field such as dermatology and radiology have shown good result applying CNN as assisting diagnostic tool[21,22], yet in orthodontic filed, it has started to get attention gradually.

The use of AI in Orthodontics is, for the moment, limited to supervised learning such as objects or point recognition. The best example is cephalometric software programs such as WEBceph™ or AudaxCeph™, Cephio™, CephX™, DentaliQOrtho™, EYES.OF.AI™, and FPT-Software™ which are trained to recognize points in cephalometric radiographs to facilitate cephalometric analyses.[23] For clinical purposes, Cephalometric Landmark Identification data could readily be extended even to predict and visualize soft-tissue changes after treatment. The application of AI in automated cephalometric landmark identification may lessen the burden and alleviate human errors.

Tracing of cephalometric radiographs can either be done manually or digitally with computer aid. Although the use of computers for cephalometric tracing aims to save time by reducing tracking errors and increasing the diagnostic value of cephalometric analysis, the inconsistency in identifying anatomical landmarks is still a major source of random error.[24]

Application of AI for determining need for orthodontic extractions

Decidingthe orthodontic extraction is one of the major and crucial decision which has a major impact on the prognosis of the treatment. It is considered crucial as the extraction process is irreversible. A clinician's decision is based on his clinical knowledge, expertise and based on the results of the diagnostic tests.[25] There is often a difference in the clinical decision making and variability in the treatment planning among the clinicians,[26] decision making is also dependent on the clinical experience of the practioners.[27] In the recent years AI technology have been used on deciding the need for orthodontic extraction. A study used an ANN based AI model for deciding if extractions are necessary prior to orthodontic treatment. The model demonstrated remarkable results with 80% accuracy and proved to be an effective tool for decision making,[28] these results were similar to the results of another study based on AI technology which demonstrated even higher accuracy of 92% and this also can be considered as an effective model.[29] The results of these studies suggest that these AI based automated systems can be of great use for clinical decision making, and can be used as an auxiliary support for especially those who are having a lesser clinical experience.

Orthognathic surgery

Great investment has been made in research and development of digital orthodontics and 3D simulation of orthognathic surgery.[30] Besides, automated treatment planning and customized surgical set up planning led to improved diagnostic precision especially among inexperienced doctors.[31,32]Knoops et al. developed a machine learning framework for automated diagnosis and computer-assisted planning in plastic and reconstructive surgery.[33] They presented the large-scale clinical 3D morphable model (3DMM), a machine-learning framework including supervised learning constructed with surface 3D scan. The model was trained with 4261 faces of healthy volunteers and orthognathic surgery patients. Through automated image processing, it provides binary outcome whether someone should be referred to a specialist with 95.5% sensitivity and 95.2% specificity.

Then, a specialist can automatically produce 3D simulation of post-surgical outcome with mean accuracy of 1.1±0.3 mm, without the need for conventional time-consuming computer assisted surgical simulation. However, only surface scan was used in this study, so the underline bone movement needed to be calculated according to soft tissue movement which remain a big task nowadays.

Estimation of growth and development

Timing is one of the main components of orthodontic treatment. Growth and development can be estimated by anthropometric indicators like chronologic age, menarche, vocal changes, height increase and skeletal maturation (skeletal age)[34]. Radiographs are widely used for detection of skeletal maturation indicators[35]. Deep learning (a machine learning algorithm that uses multiple layers to progressively extract higher level features from the raw input) and AI technologies were used by several authors to automate the age estimation by examining hand and wrist radiographs. With deep learning ability, AI systems can evaluate the radiographs after the input of a vast database consists of race, age, and gender. Results show that the AI systems can evaluate the skeletal maturity with a performance like a radiologist.[36,37,38,39]

Maturation levels of cervical vertebrae are also used for assessment of skeletal maturity. Kök et al. (2019) compared seven different, widely used AI algorithms to estimate cervical vertebrae maturation levels. Artificial Neural Networks (ANN) algorithm, which is a mathematical model of human nervous system formed by artificial nerve cells, showed better results. The authors concluded that ANN could be used in the future applications for determining cervical vertebrae stage.

Conclusion and summary

It is quite clear that AI technology has a significant impact on the dental field, and so far, there have been major investments in this field. Although early attempts showed apparent deficiency, improvement in AI area is accelerating. Artificial intelligence can be a useful and practical tool for minimizing errors and improving patient care.

Even if some of the reports on the accomplishments of the latest algorithms seem revolutionary, the applications for this technology are narrow and difficult to implement. It will be up to the orthodontic profession to adapt to this new and highly disturbing environment. Currently, the bulk of the research is performed by companies leaving the orthodontic profession in a potential vulnerable position.

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