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A Guide to AI in Orthodontics

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Abstract

The use of AI in dental practice is now becoming common. The patient's expectation of diagnosis and treatment planning supported by AI has become mandatory in a clinic. Only if we have a basic knowledge about AI, can we comprehend what is done for the patient. This review article aims at providing an indepth knowledge what an orthodontist should know regarding AI. Though much is spoken about AI in literature, the basic background of AI still remains abtract to a dentist. This article unravels the hidden mystery behind AI. The meaning of the terms used in AI is explained with suitable examples. Starting with the paradigm shift in AI, the types of knowledge dealt is also mentioned. The basic three types of model-based studies are explained in detail. Moreover, the detailed orthodontic implications of AI are also explained with relevant references. This review article would definitely be a valuable guide for those who would like to do an AI based thesis or study.

Keywords: *Artificial Intelligence, Machine Learning, Neural Network, Orthodontic Implications of AI, Symbolic AI.*

Introduction

Artificial Intelligence (AI) is commonly defined as ‘‘a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation’’.

It is obvious that technology has exceeded our humanity. But we should remember one thing, technology is not only a useful servant but also a dangerous master. In this article we would discuss what AI actually is and its implications in orthodontics [1].

Historic Background

John McCarthy an American computer scientist was one of the founders of the discipline of artificial intelligence way back in 1940. Arthur Lee Samuel was an American pioneer in the field of computer gaming and artificial intelligence. He popularised the term machine learning in 1959 [2].

The issue of the first global report by the WHO in June 2021 was indeed the turning point in artificial intelligence related to health. This report is a valuable guide for countries on how to maximise the benefit of AI while minimise its risk and avoid its pit falls.

Significance of AI studies

The main reason explaining the actual superiority of AI over human doctors is that machines can be educated with hundreds of thousands of clinical cases. This exceeds by far the clinical experience of even the best specialists in any field.

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The fear that machines could potentially replace human doctors in the near future is to be taken seriously as the momentum of change in the field of AI research is unprecedented.

Because of the huge amount of data analysed, it is likely that in the near future, AI-powered clinical studies would be statistically more powerful and accurate than ‘‘classic’’ clinical studies including double-blind randomized controlled trials.

Paradigm in AI

Symbolic AI is a technique that is based on structuring the algorithm in a human readable symbolic manner. This category was a paradigm of AI research until the late 1980s and was widely known as GOFAI which is an acronym for Good Old fashion AI.

The current trend is machine learning. The fundamental difference between machine learning and symbolic AI is that in machine learning, the models learn from examples rather than a set of rules established by a human. In this way, the algorithm shifts from rules on how to tackle a problem to rules on how to learn from data available.

Types of Knowledge in AI

Explicit knowledge, which is transparent, easily understood and explainable.

Implicit knowledge which is less transparent and more difficult to explain.

A good example, for this is playing chess. In explicit knowledge, we play chess. There is a set of rules that we have to follow, and we can easily explain the rules but the difference from implicit knowledge, is how we use the knowledge to win a game. This is very difficult to explain and understand.

However, machine learning is limited to information available at the time that the system was developed. Continuous updates are required to ensure that the information is correct and current [3].

Types of Machine Learning Algorithms

Based on the nature of learning and the design outcome of the algorithms machine learning can be of three types.

Supervised learning-supervised learning is mainly used for classification when the data are discrete and for prediction if the data is continuous. It is supervised because it is based on known outcome. The system learns by receiving feedback signals that either confirm or reject its performance. If the algorithm encounters new input, it will use the training data sets to link the new input data to decide the outcome. An example of supervised learning is email spam detection.

Unsupervised learning. This type of learning is mainly used to discover the structure of the data to find meaningful information. This type of learning uses clustering to explore the data and then organise it into groups based on similarities or relationships between variables. The final outcome is not known. This type of learning allows marketers to develop programs that are specific to each group of customers after clustering them based on similar interest and features the clusters could be based on sex, age, group or demographics.

Reinforced learning. This type of learning is similar to supervised learning in which the system is provided with a feedback signal, however, the feedback signal does not provide the true value. Instead, it rewards the system based on its interaction with a dynamic environment. Reinforcement learning is also known as reward system. An example of this type of learning is the chess engine, depending on the situation decides on certain moves and will reward by either winning or losing [4].

Types of Models Based Studies in Orthodontics

Diagnostic modelling: AI enabled diagnostics in dental medicine are mainly based on computer vision, the computer vision

and patterns form visual data, neural network fractionate images without losing important features to make predictions where the diagnostic problem arises. However, with all these improved facilities, definitely the clinicians say would be final [5].

Prediction models associates learned patterns with outcomes. We use the power of AI to detect learned patterns in new data and use them to predict future outcome. Predictive modelling use rules such as if then statements where, if a certain criteria is present, then the corresponding action must be taken. These systems are limited to the current human understanding of the problem and the ability to organise this understanding in an algorithmic form. Machine learning models have been proposed to predict a range of outcomes, including tooth loss, periodontitis, periimplantitis and survival with oral cancer [6].

Generative modelling. A generative AI can take raw data and learn to generate statistically probable output when prompted. A best example is the chat, GPT app. Generative modelling can actually hallucinate fabricated information and present it as factual. Limitations exists both in finding sufficient reliable training data and in the biased output that the training data can produce [7].

Types of Machine Learning Algorithm Applied in Orthodontics

1. Decision tree.
2. Naïve Bayes.
3. Neural network.
4. Support vector machine.
5. Genetic algorithm.
6. Fuzzy logic [8].

Orthodontic Implications of AI Plays

Growth analysers: Using ANN algorithms we can accurately determine the skeletal age, growth and development of the patient using the hand wrist radiographs and cervical vertebrae. Hatice Kok et al did a study to determine growth and development and gender determination using cervical vertebrae. Out of the 24 different ANN models, in his ANN model-7 the accuracy value of predicting growth was 0.9427 and the accuracy of gender determination was 0.895 [9].

Growth prediction: this is significant since the need for growth modulation or surgical management of skeletal problems could be decided using AI studies. Tania did a cephalometric study to predict the mandibular morphology in skeletal class 1, 2, and 3 cases. She used ANN and support vector regression and noticed that higher coefficient of predictability was noticed in ANN than SVR [10].

Diagnosis of Congenital Genetic Diseases

It is extremely important to diagnose congenital genetic diseases because many syndromes have recognisable facial features. These changes in facial morphology are often of significant orthodontic interest. One advancement is the mobile phone application called Face 2 gene FDNA, Boston, USA. The diagnostic hypothesis established by the app has already proved to be useful for Caucassians and Asians and outperformed clinicians in diagnosing a number of syndromes.

Diagnosis of Adenoids

Yan ying did a study to automatically detect adenoids. He used Fussy logic algorithm for the study and the results outperformed other methods to detect adenoids [11].

TMJOA Classification

This is important since the treatment for a TMJOA patient depends on the stage of arthritis. Shoukri et al used ANN to stage condylar morphology in TMJOA patients. In their study they used neural network biomarkers which was able to detect variations in proteins expression levels, clinical symptoms and condylar surface morphology.

The classification by ANN was almost perfect as per the study [12].

Cephalometric

AI can act as integral part in cephalometrics. AI provides facility to automatically identify the landmarks instead of plotting it manually with an accuracy of almost 95%. Provides Excellent accuracy in cephalometric values. All the analysis such as the Downs, Tweeds etc could be accurately determined and kept ready in no time by AI.

Model Analysis

Could be done within a fraction of a second just by scanning the model and uploading in the software.

Cleft Studies

Numerous studies are done in cleft lip and palate using AI. Deep learning models revolutionise the diagnostic process and predicts the susceptibility to cleft lip and palate It can also point out the intricate genetic and environment factors contributing to cleft lip and palate. Wagon et al did a study to diagnose maxillary defects. CBCT of sixty patients with unilateral cleft palate was taken. The success rate of the deep learning algorithm to assess the maxillary defects was 96% which surpassed manual methods proving large scale clinical application in cleft studies in the future [13].

Evaluation of Facial Attractiveness

Ziaonan did a study to assess facial attractiveness from orthodontic photographs. 69 orthodontic experts ranked the photographs from most attractive to least attractive. The average coincidence rate with Support Vector Regression was 71.8%. Thus, geometric morphometrics with SVR is the best method to rank facial attractiveness in the near future [14].

Prediction of Treatment Prognosis

Bo-mi et al used feature wrapping method to show highest classification accuracy in prognosis prediction for class 3 malocclusion. He took AB to MP angle as the highest significant value for prognosis prediction. If the value was less, then it was hyperdivergent with a poor prognosis. The next significant value was A to N if class 3 was due to maxillary deficiency. In this study, the feature wrapping method showed 97.2% accuracy in classification than conventional discriminant analysis which had an accuracy of 92.1% [15].

Treatment Plan

Dentists are always in dilemma whether to extract teeth or not. Xie at al constructed a decision-making expert system for orthodontic treatment to decide whether to Extraction is needed by using back propagation. The constructed ANN in this study showed 80% accuracy [16].

Jung also did a study on extraction diagnosis. He constructed neural network model combined with back propagation algorithm. The success rate of the model was 93 percentage for the diagnosis of Extraction on non- Extraction therapy and 84 for the selection of Extraction pattern [17].

Li et al used 302 cases, here, along with extraction treatment plan the anchorage pattern also was determined with deep learning algorithm using ANN. The study concluded that there was 94% success in predicting need for extraction, accuracy of predicting anchorage pattern was 92.8% [18].

Mridul ‘s study was also to decide upon extraction pattern AI based models were compared with conventional techniques for prediction extraction pattern in patients. They used CNN in 630 patients and proved that in 65.12% of extraction cases and 62.96% of non extraction cases, AI was in agreement with results of conventional model analysis in deciding extraction treatment plan [19].

Selecting the Appliance of Choice

A class 2 patient could be treated with a twin block, activator, FR2 or even a headgear. Headgear could be straight pull, occipital pull or cervical pull type. So which type of appliance should we give? OKAN developed a computer assisted method to select the type of head gear needed for class 2 patients. He selected 85 patients and plotted their SN to MP angle, overjet and overbite. Fussy logic was used with a rule if ANB was 4.8, overbite 1.6mm, overjet was 6.6mm and MP angle of 38% then medium or high pull headgear was to be prescribed. The examiners agreement was a satisfaction rate of 95.6% [20].

AI in Orthognathic Surgery

Ai provides 3d printing technology of surgical splints. It tells you where exactly and how much of surgical correction is required for the patient. It also guides us in placement of mini plates in orthognathic surgeries. It also predicts the post operative pictures of patients even before the treatment. Choi et al did a study using ANN obtained from 12 measurements to determine extraction pattern for surgical cases. The success rate of the model showed 96% for whether the patient needed surgical treatment and 91 percentage for the detailed diagnosis of surgery type and extraction decision. Weichel et al developed a computer assisted planning system based on CT metric, plaster models and photostat of head using gradient descent algorithm. Good general agreement was noticed between AI models and orthodontist. But it is a preliminary study only with 5 patients [21].

3D Aligners

Everyone one prefer an Invisalign over a bracket or a retainer using the 3d printing technology. The algorithms are industry secrets. The truth is that the point where AI algorithm and marketing strategies begin is unknown. It is an excellent tool to help to choose the best way to move a tooth or a group of teeth, but there are several drawbacks.

It completely ignores the existence of oral diseases and possible previous health treatment that may affect the orthodontic prescription.

They do not incorporate patients' facial analysis, their proportions and aesthetics.

It does not consider the impact of functional problems and stability of the tooth position. It cannot determine the aetiology of the problem and the retention strategies.

AI algorithms do not incorporate any many orthodontic tools like skeletal anchorage, dental extraction and integrated restorative procedures.

There are mechanical limitations of Aligners to control certain complex tooth movements.

Now finally let's see Buschang's study where he compared STL format of 3d clincheck models with STL format of actual post treatment models. He used ABO's objective grading system with features like alignment, marginal ridges, inclination, occlusal contacts, occlusal relation, overjet and interproximal contacts. He noticed that the clinchek models did not reflect the patient's final occlusion. Thus, AI's prediction of tooth movement was not reliable [22].

Future of AI in Orthodontics

AI have been applied to robotic surgeries in neurological, gynaecological, cardiothoracic and numerous general surgical procedures promising in the near future that AI robotic technology could be applied to orthognathic surgery as well. It can reduce infection rate because only robots have contact with a patient, higher precision of jaw movement can be expected at the same time. One of the most common criticisms against AI technology stems from the fear that corporate initiatives will exclude expert clinicians from the health care system and reduce treatment cost by AI systems. Diagnostic and therapeutic

philosophy are going through a paradigm shift from traditional signs and symptoms approach to precision medicine approach were one day we would be suggested like – Roth prescription to lose upper and lower anterior torque, tipedge prescription if tipping is needed. The archwire suggestion for each specific case would be suggested by the system making it simply super cool for us.

Conclusion

AI can be used as a tool in all ways possible to enhance the efficiency increase the accuracy and provide better treatment for the Patient.AI is technology but never a doctor. A patients need is completely fulfilled with the human touch always. So, AI and orthodontist should definitely work in harmony.

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