Review Article

Artificial intelligence and machine learning: The new paradigm in orthodontic practice

ABSTRACT

Artificial intelligence (AI) and machine learning (ML) are powerful tools that can be utilized to overcome some of the clinical problems that orthodontists face daily. With the availability of more data, better AI and ML systems should be expected to be developed that will help orthodontists to practise more efficiently and improve the quality of care. AI is a subfield of computer science concerned with developing computers and programs that have the ability to perceive information and reason, and ultimately, convert that information into intelligent actions. The future may be purely digitized, at the comforts of our home, with orthodontists developing neural programs with orthodontic decision markers to aid in developing AI for patients to take less visits, make more use of their time using orthodontic appliances, and enhance the quality of work. This article will briefly discuss the contributions AI and ML in orthodontics, its history and various uses in orthodontics in specific, and the possibility of development.

Keywords: Artificial intelligence, machine learning, orthodontic diagnosis, treatment planning

INTRODUCTION

Orthodontics being one of the most recently developed and highly researched specialties in the world shows an affinity toward growing technological advances and artificial intelligence (AI) is of no exemption.

AI is a subfield of computer science concerned with developing computers and programs that have the ability to perceive information and reason, and ultimately, convert that information into intelligent actions.[1]

AI as a science is very broad and encompasses various fields, including reasoning, natural language processing, planning, and machine learning (ML).[2,3]

Broadly speaking, AI is the behavior of nonbiological entities that perceive, learn, or react to complex environments.[3] AI is not a computational tool that necessarily mimics the workings of the human brain; rather, it is a set of tools for problem solving, each with its own specific rules.[4]

Today, there are numerous discoveries and programs pertinent only to the development of AI in the specialty of Orthodontics such as Dental Monitoring by RMO and Aerodentis in Israel to name a few.[5-7]

Similarly, ML is concerned with making machines and computers capable of learning from previous experiences, data, or examples. By utilizing a mixture of statistical and probabilistic tools, machines can learn from previous examples and improve their actions when new data are introduced.[8,9] This could be in the form

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of predictions, identifying new patterns or classifying new data.[10]

This article will briefly discuss the contributions AI and ML in orthodontics, its history and various uses in orthodontics in specific, and the possibility of development.

ARTIFICIAL INTELLIGENCE MEANS

AI is ML, or more scientifically defined as computational intelligence, designed and formulated to work in an environmental setup without further assistance (Poole, Mackworth, and Goebel 1998).

Research is being performed in the field of AI to achieve human-like generality. However, most of the progress on AI has been on models that focus on a single problem, having a constrained set of rules and problems such as playing chess or identifying caries from X-ray scans. For many of these problems, computers far surpass human results.[8]

AI for the layman immediately pertains to talking robots, automated home living, and convenient transport systems. However, AI is not only about robots but also about understanding the nature of intelligent thought and action using computers as experimental devices.[9]

While an AI model can be classified as narrow or general on the basis of its problem-solving capabilities, from an algorithmic perspective, there are two main categories of AI: symbolic AI and ML.

Symbolic AI is a collection of techniques that are based on structuring the algorithm in a human-readable symbolic manner. This category was the paradigm of AI research until the late 1980s and is widely known as good old-fashioned AI.

Thus far, no tools exist to lead patients and clinicians out of the decision-making uncertainty, in which they are trapped when they face a condition that has several possible correct treatment options – though some better than others. It is in this context that AI can make a significant contribution.[11]

HISTORY OF ARTIFICIAL INTELLIGENCE

In 1950, AI began as a concept by Alan Turing, and in 1956, American John McCarthy gave the concept a name. The modern history of AI begins with the development of stored-program electronic computers. Fast forward 68 years into the future, we have today a vast collection of AI inspired apps, programs, and inventions, some of the great contributions belonged to the industry of orthodontics.

AI started back in 1943,[12] but it was not until 1956 that the term "AI" was first used during a conference held at Dartmouth College.[13] A few years later, the term "ML" was officially applied to a checkers-playing program, considered one of the first successful self-learning tools

One particular application to the development of AI in the history of medical sciences was in 1958, a psychologist named Dr. Frank Rosenblatt developed perceptron which worked on a multilayer feed-forward mechanism.

Another technology came when Paul Werbos, in 1974, introduced "*back-propagation*" learning. Today, we use this ability of the computers programs to "learn" from newer information to aid health-care professionals all over the world to better understand diseases, to diagnose them early, and to treat them effectively while also sharing this vital information with other health-care professionals worldwide.

ARTIFICIAL INTELLIGENCE AND ORTHODONTICS

Dentistry in general and orthodontic specifically has applied AI to solve many different problems. Early attempts to use AI in dentistry and orthodontics were in the form of knowledge-based ES. These systems were mainly aimed at helping nonspecialist dentists to develop diagnoses and treatment plans.

Dhaimade *et al*. (2017), the culmination of AI along with digitization, has seen a new era in the field of dentistry and its future aspects appear extremely promising.[14-19]

The future may be purely digitized, at the comforts of our home, with orthodontists developing neural programs with orthodontic decision markers to aid in developing AI for patients to take less visits, make more use of their time using orthodontic appliances, and enhance the quality of work.

It would be beneficial for orthodontic specialists to familiarize themselves with advanced user control interfaces pertinent in moving forward into a purely digitized future. Collaborating with computer scientists and developing orthodontic appliances tested and validated using various programs can be helpful in developing AI in orthodontics.

A study by Takada *et al*., in 2016, stated that AI expert systems with neural network ML could be useful in orthodontics and that improved performance was achieved by components such as (1) proper selection of the input data, (2) appropriate organization of the modeling, and (3) preferable generalization.

TYPES OF MACHINE LEARNING

ML algorithms are divided into three main types based on the nature of learning and the desired outcome of the algorithm.[20]

1. Supervised learning
2. Unsupervised learning
3. Reinforced learning.

MACHINE LEARNING FOR DIAGNOSIS AND ORTHODONTIC TREATMENT PLANNING

One of the dilemmas during treatment planning is deciding whether or not to extract, with substantial variability between orthodontists' decisions. This has led to the development of several decision support systems that reduce the subjectivity of making decisions – artificial neural networks (ANNs).

Recently, a paper used ANN to identify anchorage requirements in cases that were determined by the system to need extractions and it was accurate 83% of the time.

X-ray analysis, an integral part of diagnosis and treatment planning, has also benefited from ML. One of the most important applications of ML in orthodontics was the automation of landmark detections. A recent systematic review reported 5%–15% better accuracy of landmark detection with ML than traditional methods.[12]

Neural networks were used to estimate patients' dental ages from panoramic radiographs. Its RMSE was 0.9 for girls and 1.1 for boys, while traditional regression had an RMSE of 1.3 and 1.4 for girls and boys, respectively.[21]

Panoramic and lateral cephalometric X-rays have also been used to predict maxillary canine impactions based on angular and linear measures. The highest prediction accuracy was obtained with a random forest algorithm, which correctly predicted the actual eruption status of canines 88.3% of the time.[22]

MACHINE LEARNING FOR TOOTH MOVEMENT PLANNING

The use of AI for assisting in orthodontic treatment planning has apparently been a reality for some time. More than one Aligner Company claims to use AI algorithms to optimize orthodontic planning, thereby saving the time of orthodontists in this process. Since these algorithms are industry secrets, the truth is that the point where AI algorithms end and marketing strategies begin is unknown.[11]

AI is an excellent tool to help orthodontists to choose the best way to move, for instance, a tooth or group of teeth from point A to point B, once the orthodontist instructs the machine where the final position should be. This is useful because orthodontics performed in a totally traditional way – with brackets only – require high manual skill, and many professionals do not have or have not received the proper training to develop it. AI assists these dentists, but there are several limitations of ML in contemporary aligner treatment.[11]

Another limitation of AI algorithms being implemented today is that they do not incorporate patients' facial analysis, their proportions, and esthetics.[23,24]

There is a direct interaction between orthodontic dental movements and facial esthetics. Only a qualified orthodontist can perform these analyses because tooth movement in any direction of the space is commonly connected with facial and smile esthetics.[25]

Recently, decision support systems were developed to determine the geometry of orthodontic springs used to close extraction spaces[26] and to determine the forces needed to align teeth, but neither system has been applied clinically.[27] Another orthodontic challenge during treatment planning is predicting the size of unerupted teeth. To address this, a hybrid system using ANN and genetic algorithms was used to predict canine and premolar sizes.[28]

MACHINE LEARNING AND TREATMENT OUTCOMES

One of the more useful applications of AI in orthodontics is the prediction of soft-tissue treatment outcomes. Predictions of treatment outcomes in Class II and Class III patients have also been reported.[14-19] Using ANN, predictive models were developed to predict the posttreatment peer assessment rating (PAR) index in Class II patients based on their pretreatment PAR index.[29]

Recently, ANN was used to predict the change in lip curvature after orthodontic treatment with or without extractions.[30] Its prediction of change and the actual change that occurred differed by 29.6% and 7% for the upper and lower lips, respectively. Both the predictions were much better than those based on linear regression.

The system was then applied to a treated sample where it showed that all of the unsuccessful cases belonged to either the hypermandibular or the hyperdivergent cluster. Another system was able to correctly predict the prognosis of Class III treatment (97.2% of the time), which was slightly better than 92.1% reported for discriminant analysis.[31]

Using ANN, facial attractiveness was quantified on a scale from 0 to 100 (0 extremely unattractive and 100 extremely attractive) before and after orthognathic surgery.[32]

MACHINE LEARNING AND GROWTH PATTERNS

Many methods have been introduced to help orthodontists to classify their patients' growth patterns. A recent study used cephalometric variables to classify patients' craniofacial growth as either normal or abnormal.[33]

One longitudinal data of untreated Class III subjects, who were classified as either good or bad growers based on the changes in their sagittal relationships, a classification tree had a significantly lower rate of misclassification (12.0%) than discriminant analysis (40.7%), both of which were based on the same 11 cephalometric variables.[34]

CONCLUSIONS

AI can assist orthodontists to choose the best way to move a tooth or group of teeth, but AI today completely ignores the existence of oral diseases, does not fully integrate facial analysis in its algorithms, and is unable to consider the impact of functional problems in treatments.

The future may be purely digitized, at the comforts of our home, with orthodontists developing neural programs with orthodontic decision markers to aid in developing AI for patients to take less visits, make more use of their time using orthodontic appliances, and enhance the quality of work.

AI and ML systems applied in orthodontics provide promising tools that can improve clinical practice. These clinical decision support systems can help orthodontists to practise more efficiently, reduce variability, and eliminate subjectivity.[35] The accuracy of most systems presently available is considered good to excellent, ranging from approximately 64% to 97%.

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Conflicts of interest

There are no conflicts of interest.

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