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The Promises and Potentials for Artificial Intelligence in Orthodontics; A Review Article

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Abstract:

Background: For the last two decades, numerous work fields have been developed, two of those fields are artificial intelligence (AI) and machine learning (ML). In both medicine and dentistry fields there have been several applications of AI and ML. However, despite encouraging results, its application in the treatment of irregularities in the teeth (orthodontics) has developed slowly. The current body of literature on AI and machine learning applications in orthodontics has received insufficient notice and evaluation. This is unfortunate since Orthodontics with its inherent focus on patterns, models and predictions is in prime position to reap the benefits of AI and ML. Advances in AI are not limited to just theories and models, they offer much needed clinical insights that further empower both expert and novice practitioner. AI also provides important heuristics in areas that have been traditionally contentious for Orthodontists, such as decisions of extractions and Orthognathic surgery. The findings of this review herald the most recent advances of AI in multiple facets of Orthodontics. From diagnosis to treatment planning and visualization to assessment of debatable subjects like beauty and growth prediction Aim: This brief review article intends to provide the orthodontics dentists with a knowledge of both AI and ML and their applications.

Keywords: Machine learning (ML), Artificial intelligence (AI), Orthodontics, Craniofacial growth.

1. Introduction

One of the computer science's field area is the Artificial intelligence (AI), which related with the creation of programs capable of perceiving information, reasoning, and eventually switching that information into several actions intellectual. (1-3)

At the moment, machine learning (ML) is considered as a popular AI application in both medicine and dentistry. The Artificial intelligence work field has begun during last century و about 1943,(4) However, the expression of "artificial intelligence" was not stated until 1956 during a symposium maintained at Dartmouth College.(5) Many years after, the phrase "machine learning" was utilized mentioning a checkers-playing program. Machine learning is related to permitting both machines and computers to learn from previous observed data, examples and earlier experiences.

The expert system (ES) is a computer application that handles data and information. It consists mainly of a knowledge base and an inference machine. It replicates expert decision-making and work procedures while addressing real-world challenges in a single subject.(5)

This review aims to brief interested Orthodontists about the key concepts behind AI and Ml, and to give a concise appraisal of their current and potential applications.

2. MATERIALS AND METHODOLOGY

In order to conduct a thorough review article on AI in Orthodontics, the authors performed an online search spanning several electronic databases, including PubMed, SCOPUS, , and Science Direct. The search used Medical-Subject-Headings (MeSH) terms/keywords such as:" Artificial Intelligence (AI)", "Machine Learning (ML)", "AI in Orthodontics", "Artificial Neural Networks (ANN) in Orthodontics". Besides the aforementioned electronic searches, cross-references and several textbooks were manually scanned for pertinent additions to the topic. Articles published in English between the year 1996 and 2024 that fulfilled the review's goals were included. The article selection procedure included analyzing the inclusion and exclusion criteria, as well as assessing the studies' quality. Our preliminary search yielded 612 articles, of which 121 articles were chosen according to their titles and abstracts. Further appraisal according to inclusion and exclusion criteria narrowed the number down to 26 studies and 7 manually identified relevant sections of textbooks.

Types of ML

Algorithms of machine learning are consists of three essential categories (6) [Figure 1] These three categories are mainly depending on the learning-environment and the required results of algorithm, and can be listed as follows:

Supervised learning (SL):

As a category of ML algorithms, SL is mainly utilized for grouping categorical data and prediction of continuous data (regression). It is based on an earlier determined outcome. The output results can be predetermined by using the training data sets in case if providing both algorithm and fresh input data. As an example, E-mail spam detection is an easily visible form of supervised learning.

Un-supervised learning (UN-SL):

This type of learning is used mainly to discover the formation of data targeting to find significant sectors of information. Clustering is the process of data-scanning and grouping these data into groups according to similarity or relationship between different variables.(7) The groups could be created according to sex, age, or demographics.

Reinforcement learning (RL)

RL is a type of learning like SL, includes receiving a feedback signal. However, this feedback signal does not reflect the actual value in accuracy. The system responds depending on interactions with a dynamic environment.

Chess engines are a common illustration of this type of learning. According to condition (i.e., the environment), the computer chooses specific movements and is satisfied by either winning or losing.(7)

Deep learning (DL) is a subdivision of ML in which the computer determines definite properties of an input. Artificial neural network (ANN) was firstly constructed in the 1900s, and it is the forerunner of deep learning. The neural network is now better known as "deep learning." (8)

AI AND ORTHODONTICS:

ANNs have a huge ability to help in clinical decision-making. To obtain dependable results for patients, orthodontic cares should be sensitively designed. However, it is uncommon to see teeth extracted as part of an orthodontic treatment plan. As a result, it is vital to make the best clinical judgment before starting irreversible operations. In individuals with malocclusion, an artificial neural network was employed to help determine the requirement for tooth removal before orthodontic intervention.

Using artificial intelligence to identify cephalometric landmarks:

Cephalometric analysis is recognized as a valuable tool for diagnosis and therapy planning (9) Artificial intelligence-powered automated algorithms for cephalometric analysis have been evaluated in various studies (10-12). A study using Cellular-Neural-Networks (CNN) aimed to assess the precision in detecting landmarks of cephalometric on radiographs. Results of this mentioned study were hopeful, with respectable performance for the created model (13). These findings were congruent with those of other study, which used a Paraconsistent-Artificial-Neural-Network (PANN) to investigate cephalometric factors for orthodontic diagnosis. The findings of this investigation were moderately encouraging, and the model's performance was comparable to that of the specialist. (14).

Landmark and Segmentation identification

The process of image segmentation is performed by isolating the pixels of specific organ's medical images as obtained in X-rays, CT scans, or MRI (15)

A relatively recent study devised a process for automatic segmentation of both maxilla and mandible by using CBCT (16). They used a learning-based-framework to isolate both the maxilla and mandible from CBCT using a random forest.

Dice-ratio is a common tool for estimating volumetric-segmentation of medical imageries. The definition is the total of the learned and ground truth sets' intersection voxels times 2- divided by the sum of the respective voxels. As the Dice-ratio is one, it implies a accurate match among the learnt and ground truth sets, while null shows no similarity. (17) In this investigation, 30 CBCTs were validated against a manually labeled ground truth. The standard dice ratios for the mandible and maxilla were 0.94 and 0.91, respectively (18)

Diagnosis and planning of orthodontic treatment using ML.

The decision whether or not to extract, is one of the most popular problem during the treatment planning, even with the differences of this decision among orthodontists (19) This encourages creating several decision supporting systems to lower the self- decision making. One of the related studies stated that artificial neural networks [ANNs] were found to be efficient by 80% in predicting the decision of extraction. (20) While in two other studies, they reported the effectiveness of ANN by 93% in predicting that decision.(21, 22)

Predicting and planning orthodontic treatment by AI application:

In recent years, technology of AI has been confirmed to be useful in those systems of clinical decision support to assist orthodontists in their decision-making. An investigation including technology of AI was created for anticipating the necessity for orthodontic therapy. This AI

model has proven itself successful and delivered positive results with a high degree of precision (23)

One of the problems for inexperienced orthodontists is determining the right treatment technique and purpose, including headgear. According to this, a system was established to assist orthodontists in identifying the best appropriate headgear for the situation. When the decisions of eight expert orthodontists were compared, the algorithm accurately picked the suitable headgear 95.6% of the time (24).

Using artificial intelligence to determine the necessity for orthodontic extractions:

Orthodontic-Extraction is one of the most influential decisions to make, as it has a significant impact on the treatment's outcome. It is considered a critical decision since the extraction process is permanent. Many categories controlling the clinician's choice and his decision, these categories are knowledge, expertise, diagnostic tests and model analysis.(20) Occasionally, differences in clinical decision and treatment plan among doctors may occurred. Additionally, decision-making is depending on the orthodontists' clinical track record.(25) now adays, AI technology has been utilized to assess the necessity for orthodontic extractions. In an investigation utilizing AI model based on ANN aiming to determine whether extractions were necessary before the orthodontic therapy, the model showed outstanding results with 80% accuracy and confirmed to be an effective application for decision-making.(26)

Orthognathic surgery

Orthognathic surgery us yet another irreversible facet of Orthodontics. Facilitating the process of decision making in orthognathic surgery would go a long way to further help Orthodontists with both vast and little expertise in that department. A study claimed to have created a ML algorithm for computerized diagnosis and computer-aided planning in plastic and reconstructive surgery. They created the large-scale clinical 3D morphable model (3DMM), a ML framework depending on supervised learning built on a surface 3D scan. The model was created utilizing 4261 faces of healthy volunteers and patients of orthognathic surgery. Image processing provided a dual decision on whether patient should be back to a specialist with 95.5% sensitivity and 95.2% specificity.(27)

3D simulation of post-surgical outcomes can be created with an mean precision of being 1.1±0.3 mm, eliminating the requirement for time-consuming computer-assisted surgical simulations.

Treatment outcomes with ML

One of AI useful applications in orthodontics is the prediction of soft tissue treatment outcomes. Nowadays, ANN is used in predicting the change in lip curvature after orthodontic treatment with or without extractions. Differences between the prediction change and the real change in lip curvature was about 29.6% and 7% for the upper and lower lips, respectively. Both estimates were significantly more accurate than those based on linear regression.(28)

The concept of beauty is unclear since it is independent and can be affected by age, gender, and ethnicity. Facial attractiveness was estimated by using ANN with a scale of 0 to 100 (0 extremely unattractive and 100 highly attractive) before and after orthognathic surgery. Statistically significant differences were found between the pre- and post-surgery scores, with facial attractiveness increasing by 74.7%. (29)

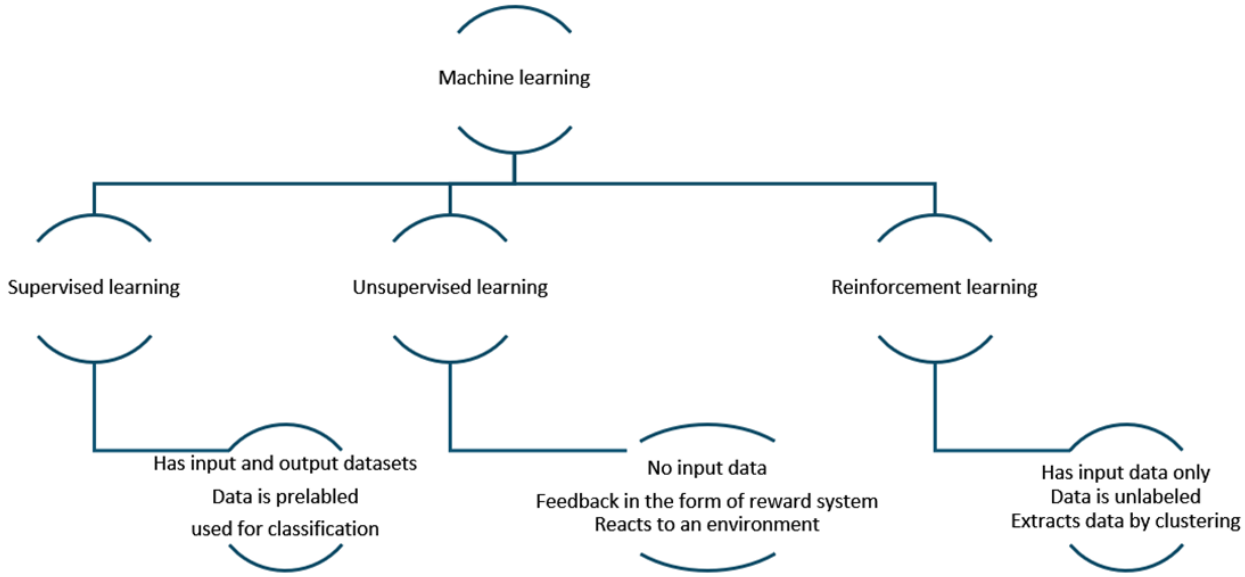

Figure 1: Different types of machine learning

ABBREVIATION LIST

Abbreviation	Meaning
AI	Artificial Intelligence
ML	Machine Learning
ES	Expert System
MeSH	Medical Subject Headings
ANN	Artificial Neural Network
3D	Three Dimensional
DL	Deep Learning
CBCT	Cone Beam Computed Tomography
PANN	Paraconsistent Artificial Neural Network
CT	Computed Tomography
MRI	Magnetic resonance Imaging

Machine Learning and Growth Patterns

Different ways were proposed to help orthodontists in the classification of patients' growth patterns.(30) in 90's of last century, ANN was utilized in growth classification for forty-three untreated children in terms of size and form changes.(31) Though, system was not authorized using an exterior sample. A current study used cephalometric traits to define the normality of patients' craniofacial growth. With a ratio of 99.8%, it was stated that support vector machines could correctly identify abnormal growth patterns.(32) Another study reported an accuracy ratio of 74.5 after using support vector machines to identify normal or pathological skeletal models based on craniofacial.(33)

CONCLUSION

Technologies of AI and ML utilized in orthodontics provide intriguing applications for improving clinical training. Technologies of clinical decision support can help orthodontists to work effectively, predictably and at the same time without subjectivity. The majority of available applications were reported to have good accuracy, ranging from 64% to 97%. The lower accuracy is expected to be improved by increasing the sample size to provide more data.

CONFLICT OF INTERESTS

Neither author has any interests conflicting or interfering with the integrity of this review.

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