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ORTHODONTICS AND AI: A COMPREHENSIVE REVIEW

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ABSTRACT

Artificial intelligence is a vastly upcoming technology that has found its way into dentistry and diagnosing various ailments. There is a lot of confusion in understanding the terminology and workflow around AI and machine learning and its associated applications in the field of orthodontics. AI has been applied for diagnosis and treatment planning, radiographic analysis, skeletal age determination, TMJ-related disorders, and remote patient monitoring. All these applications come with their disadvantages as well. This comprehensive article aims to illuminate the terms related to AI and how it has helped diagnose various subjects in orthodontics.

KEYWORDS: artificial intelligence, machine learning, diagnosis, big data.

INTRODUCTION

Orthodontics is the art and science that primarily works on the experience and planning of the orthodontist. Every malocclusion has unique characteristics and it is impossible to completely predict and correlate different possibilities portrayed in the oral cavity.1 Artificial intelligence (AI) is the upcoming technology that allows for "a means to obtain near-accurate prediction from the available data." This is achieved by simultaneously analyzing all the different malocclusion variables.[1]

In recent years, AI has made leaps and bounds with progress in making diagnosis more precise and efficient in treatment planning. This helps in the basic process of predicting the treatment prognosis. Nevertheless, the knowledge and expertise of a clinician remain pivotal to diagnosing and planning the best possible treatment outcome for the patient.[2]

The many applications of AI in orthodontics are mostly in two major places: practice management and decision-making.[1] The following comprehensive review will discuss the basic terminologies related to AI, its diverse applications, certain drawbacks, and prospects in Orthodontics.

BASIC TERMINOLOGIES IN ARTIFICIAL INTELLIGENCE(AI)

1. **Artificial intelligence-** AI is the technology that allows a machine to have its own intelligence i: e it helps a machine to learn via the data fed to it which enables it to solve problems on its own.[1]
2. **Machine learning**(ML)— In ML, the models are trained to learn from numerous examples rather than using a defined set of rules that are established by a human.[3] Machine learning has several important functions in Orthodontics: descriptive, predictive, and prescriptive, more of which we will discuss in the following paper.[4]
3. **Supervised learning**- It is a type of machine learning that is used in classifying or predicting data based on an already known outcome. Supervised learning teaches the AI network one specific task, for example, object recognition.[4]
4. **Unsupervised learning**- The second type of machine learning that helps find hidden patterns or structures where the outcome is unknown. It uses principles like backpropagation of data and gradient descent/error analysis. These use a large dataset consisting of before and after treatment “inputs” which is fed into neural networks, without giving any rules or instructions.[1]
5. **Reinforcement learning-** A machine can develop a modification in the algorithm using previous versions that help in increasing the intended output.[1]
6. **Big data-** they are large sets of data or the combined available data of all points that are taken from multiple sources. These are used for recognizing patterns that form a customized experience for everyone.[1]
7. **Deep learning-** this is a subset of AI, which utilizes many types of neural networks. These neural networks learn to use unlabelled data, without any human supervision. They consist of multiple hidden layers which mimic the human brain’s cognitive and reasoning abilities to bring out the intelligence, closest to the human intelligence.[4]
8. **Neural networks-** these are a set of algorithms that calculate signals via artificial neurons mimicking the functioning of human neurons.[4]

9. **Artificial Neural Networks(ANN)-** ANN is modelled like the neural network of the human brain where artificial sets of neurons are present with multiple input pairs resulting in an output.[4]
10. **Convolutional neural networks(CNNs)-** CNNs imitate the action of interconnected neuron systems in the human brain cortex allowing to identify and locate specific objects in an image.[5]
11. **The "Premeditatio Malorum**"- looks at a situation and explores all the options where the situation may go wrong to avoid such negative conditions.[4]

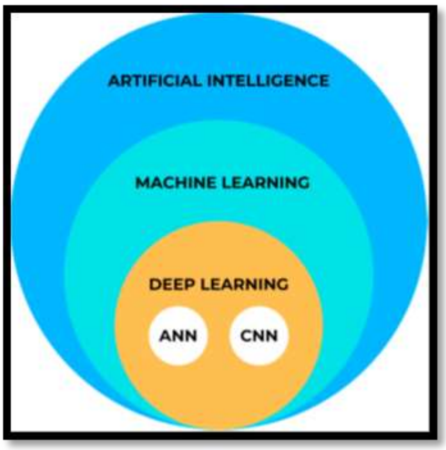

Fig.1: The umbrella of AI explained simply.

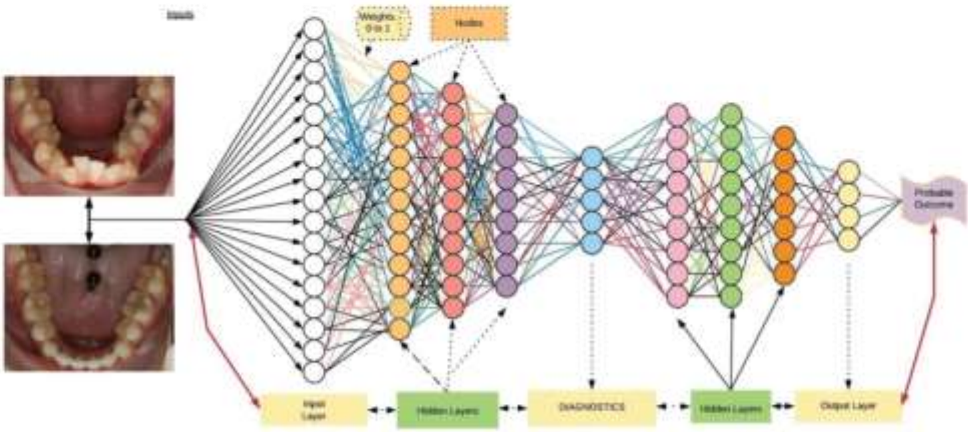

Fig.2: Architecture of the multilayer perceptron and a simple neural network10.

Applications of AI in Orthodontics

Orthodontic treatments are lengthy procedures where the average treatment time of roughly 12-30 months. Orthodontists hence are constantly adapting and improvising to reduce the treatment time and make it adept to the societal needs. Machine Learning techniques can resolve this problem.[2] Some of the recent developments in using AI in orthodontics include the following fields; we will discuss each of the applications in detail.

i. Treatment planning and outcome prediction
ii. Radiographic image analysis
iii. Skeletal age determination
iv. TMJ osteoarthritis evaluation
v. Extraction vs non- extraction decision-making
vi. Orthognathic surgery decision-making
vii. Remote patient monitoring

Treatment planning and outcome prediction

To understand how this works, it is important to understand what a neural network is and how AI uses data for the same. (Fig.3/Fig.4)

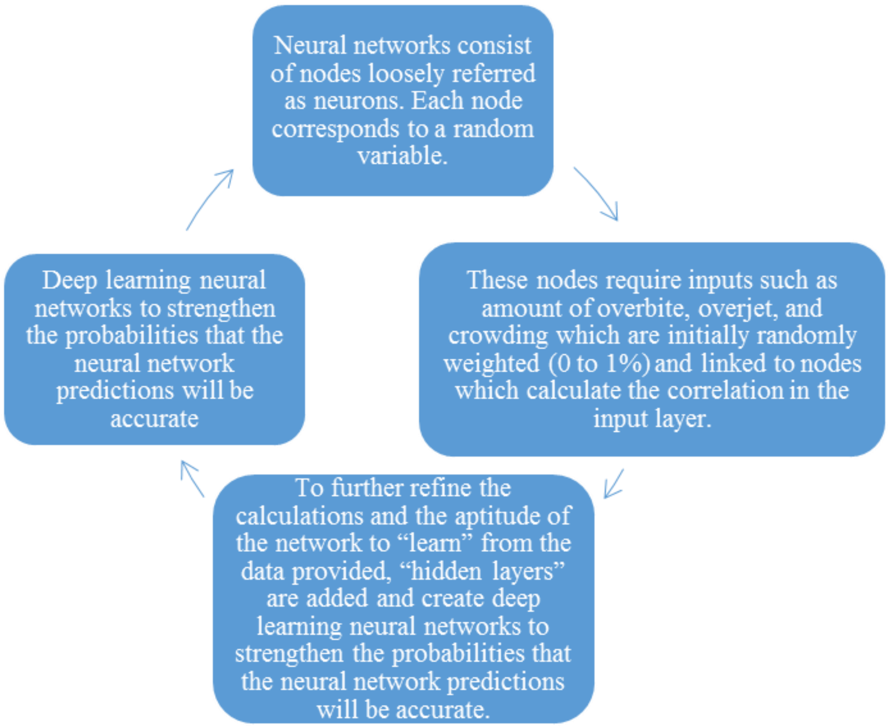

Fig.3: Neural networks in AI programming.[1]

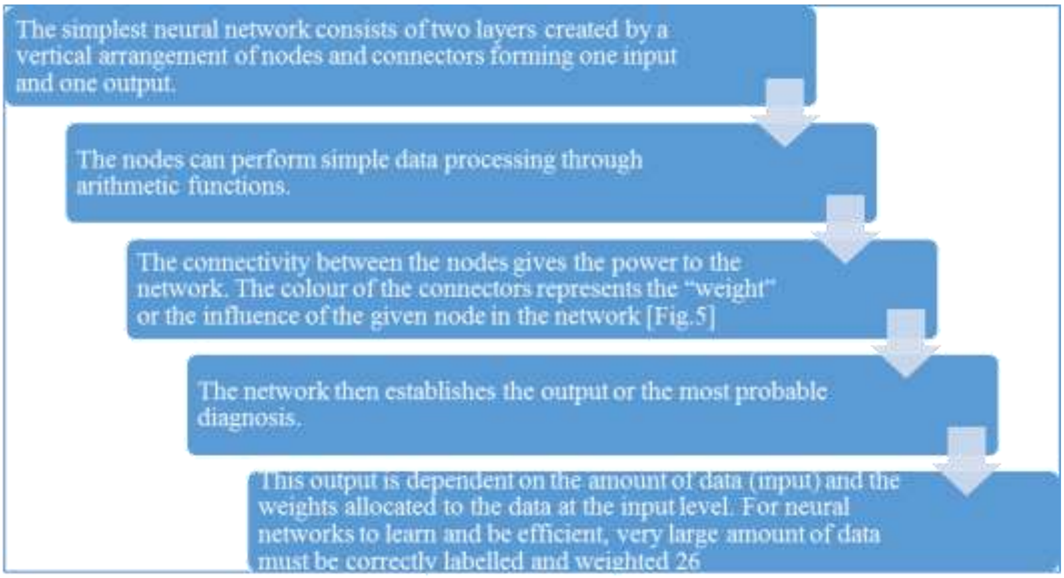

Fig.4: How does a neural network work?[1]

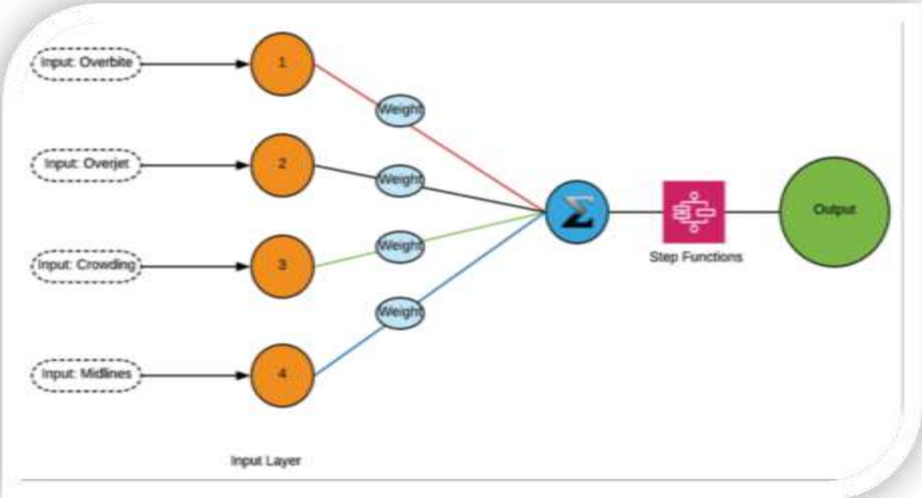

Fig.5: How does a neural network work? (diagrammatic representation)[1]

Companies like Invisalign in the late nineties introduced segmenting teeth automatically by using software like ClinCheck. This allowed the software to create tooth movement virtually and predict treatment possibilities and outcomes. This allowed the virtual correction of malocclusions in all three planes by using some expert knowledge and some AI software knowledge. Using the scanning data, distinct details can be recreated, segmented in the software, and produce realistic simulations for a possible treatment output.[6]

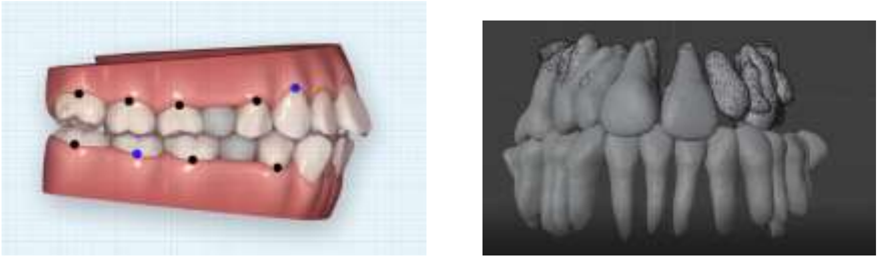

Fig. 6: teeth segmentation and virtual tooth movement.

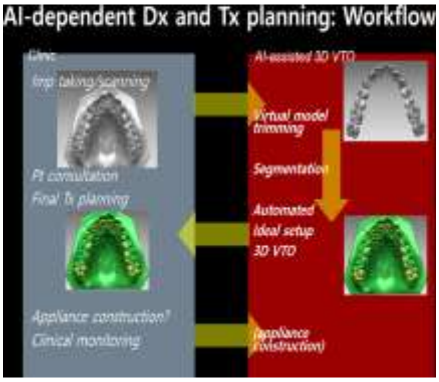

Fig.7: diagnosis and treatment planning using AI4.

Radiographic image analysis[3]

Since the beginning of using AI for the identification of cephalometric landmarks, there have been many different ways or approaches that have been developed. These are broadly grouped under 5 categories.

i) Image filtering and knowledge-based systems (where radiographic images are segmented & specific features are extracted),

ii) Model-based approaches (patterns of existing images are matched with the algorithms),

iii) Hybrid systems

iv) Deep learning

A. Image filtering and knowledge-based systems (image segmentation & feature extraction)

As the name suggests, the image segmentation is done based on the knowledge from human experts to arrive at a final conclusion. Computer applications help the inference engine to arrive at a decision from the existing knowledge base. Rule-based/expert systems are applications that correlate the input with all the information priorly loaded in the knowledge base. So sometimes due to the strict rules of existing expert data, most of the output will depend on the quality of the radiographs uploaded.

B. Model-based approaches (pattern matching algorithms),

Pattern-matching is the process in which the AI identifies structures surrounding the specific landmark and marks it. The algorithms look for multiple structures around the landmark to identify its exact location. The drawback of course is the limited number of structure identification points with no major bony landmarks nearby can lead to false or negative findings. algorithms use the morphology of structures for the automated identification of landmarks.

To overcome this problem, the knowledge-based AI application is combined with pattern matching for accurate landmark identification. Knowledge-based application helps to narrow done the exact area of the landmark after which pattern matching is done to locate the precise location of the said landmark. The four major steps in landmark detection are edge detection, contour segmentation, segment joining, and reference line detection.

Edge detection helps identify the rough contours of structures near the landmark involves the identification using a Gaussian filter. This helps to eliminate the noise in the image along with **maintaining the identified contours** of the structures. Next, **reference lines** are chosen from which the patient's head contour is created. Once this is done, areas **for landmark identification** are defined. Then a point detection module **or pattern matching** is applied using previously entered data to identify the exact position of the landmarks in the lateral cephalogram.

C. Hybrid approaches

A combination of different methods is put together like image filtering, knowledge-based, and model-based approaches. The different types are.

- Random forest regression and sparse shape composition combination.
- Data-driven image displacement estimation.
- Automatic globally-optimal pictorial structures with random decision forest
- Machine learning tree-based approach.
- Game theory and random forest technique.

Most of the above methods do not guarantee an absolute accuracy which is ideal for orthodontic diagnosis. It is suggested to correlate the findings with clinical diagnosis. A margin of 0.59 in the x-coordinate and 0.56 in the x-coordinate should be taken into consideration.

D. Deep learning

Deep learning is a part of the AI algorithm which has multiple layers of nodes each with a large dataset which is initially fed and helps in identifying complex structures or patterns from the input data. A deep learning neural network is an artificial neural network(ANN) that is created with multiple layers along with two or more hidden layers. These layers constitute the data that is fed to the AI system from an existing large dataset and help in arriving at a final output (in this case, landmark identification) from it. One of the quickly moving AI systems is the convoluted neural network(CNN) which has been used for the identification of landmarks in a cephalogram. Convolution refers to the result as well as the entire process of computing the data. These are made to mimic the human neural network and follow a multilayer perceptron kind of deep learning method.

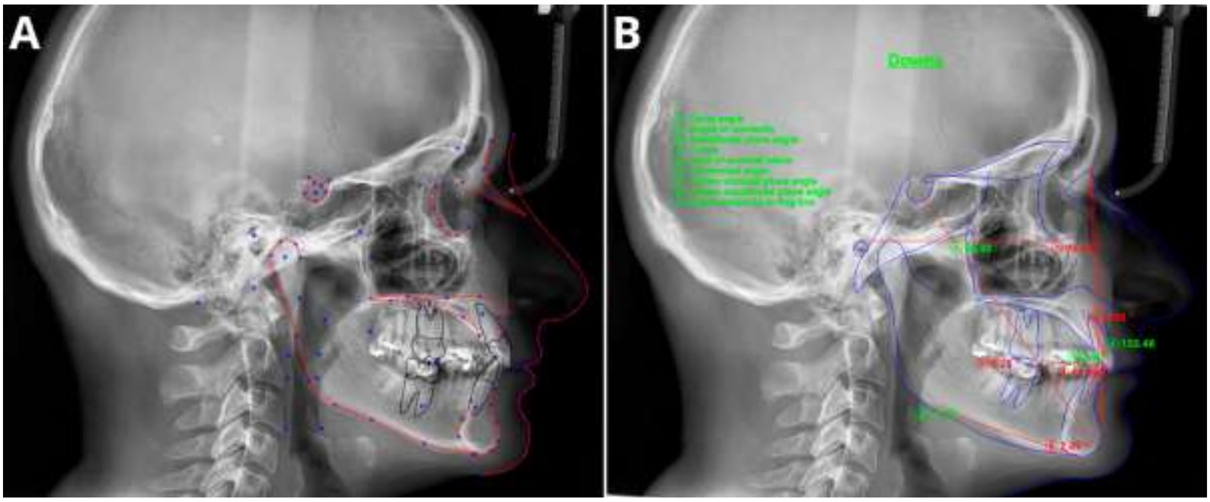

Fig. 8: identification of cephalometric landmarks using AI.

***Skeletal age determination*[6]**

Although many studies have questioned the accuracy of AI in the determination of skeletal age, Kok et al used 7 different types of machine learning methods to check for accuracy. According to their study, the algorithms showed different levels of accuracy, but the artificial neural network was the closest and most precise. Another study done by Amaya and the team also showed the ANN machine learning to be the most accurate as compared to the others. Further studies and a larger dataset could probably open more avenues to skeletal age determination with CVMI or hand-wrist radiographs for accurate diagnosis.

***TMJ osteoarthritis evaluation*[7]**

TMJ osteoarthritis is a condition that is characterized by multiple etiologies, each of which requires different examinations such as physical condition, radiographic images, CBCT, MRI, and individual biological markers. When the data from all these exams are available, it can be fed to the algorithm to train it (machine learning). This will help in creating models that predict and accurately diagnose the condition.

The two types of machine learning as mentioned initially are supervised and unsupervised methods when applied for TMJ osteoarthritis, supervised learning simply predicts the condition's presence or absence whereas unsupervised helps in the classification of TMJ-OA based on patterns identified from the initial fed dataset. The shape of the condyle is a crucial factor that helps in the identification of the condition.

The steps involved in TMJ-OA identification via AI involves the following.

- Acquisition of data and its standardization.
- Extraction of data and its assessment.
- Management of the data and its storage: in web systems and computational processing.
- Processing of data which includes: image processing, classification, and 3D segmentation (labelling).
- Artificial Intelligence: Statistical analysis, cross-validation, and machine learning models.

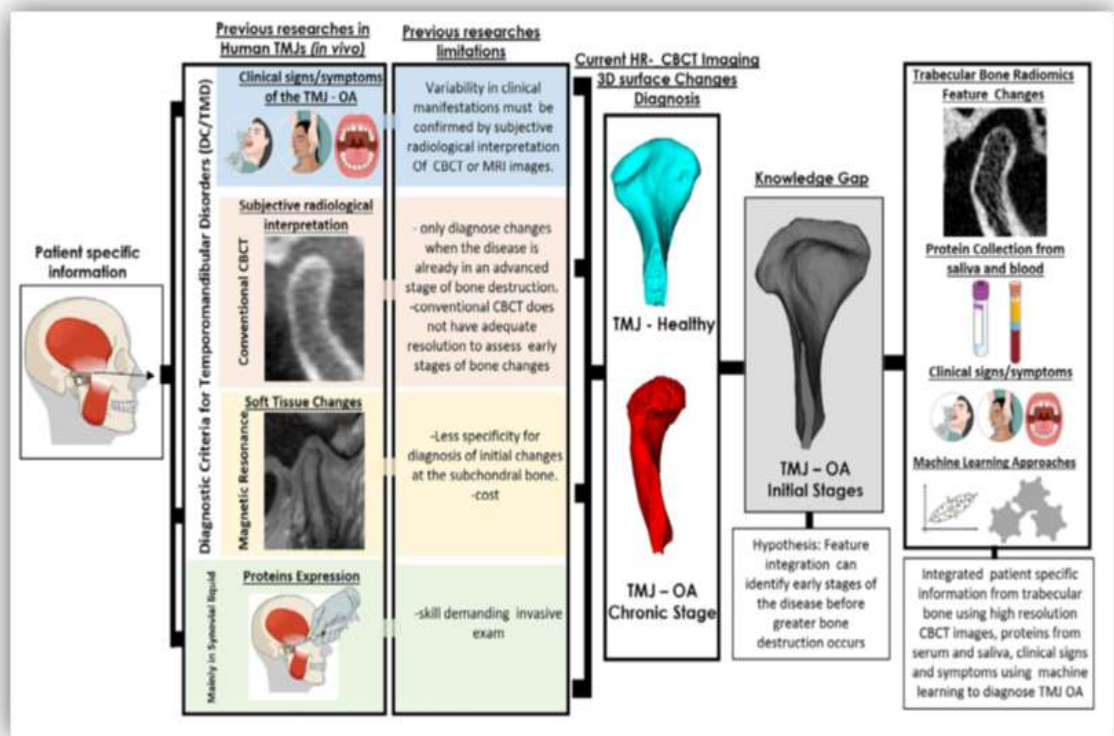

Fig.9: TMJ osteoarthritis evaluation and diagnosis using AI.

Extraction vs non- extraction decision-making

Most orthodontic treatments may require extractions for space requirements. Several factors can influence an orthodontist's decision in extraction treatment protocol including preference of the patient, treatment outcome, social status, etc. Also, the need for extractions can vary with the expertise of the orthodontist as well which is influenced by their philosophies and training. So the conclusions for treatment can differ and vary among orthodontists, especially in borderline cases.[8]

Many AI tools have been introduced to help in making the right decision in terms of extraction or non-extraction treatment plans. Studies have shown an accuracy ranging from 80-90% when compared with an expert orthodontist's analysis. Although the number of cases taken in these studies is low, it paves the way for future diagnostic decisions when it comes to the extraction line of orthodontic treatment.[8]

Maxillary molar distalization up to 4mm bilaterally using TADs or mini-screws is also an effective way to avoid upper premolar extraction treatment. A U-Net-based AI deep learning system was able to accurately show distalization results with the available datasets. can be effectively distalized with the application of a temporary skeletal.

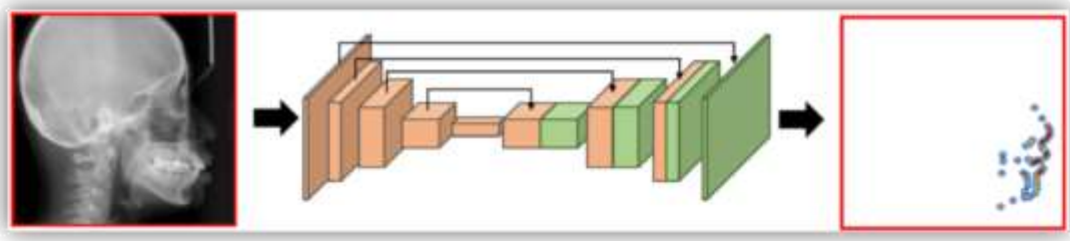

Fig.10: U-net-based deep learning app for distalization.[9]

Molar distalization can achieve an ideal incisor position in patients who have a Class II malocclusion. This can have a good effect on the soft tissue profile as well. Using a convoluted neural network has shown near accurate prediction of changes in skeletal, dental as well as changes in soft tissue using lateral cephalograms. This can help guide clinicians and also educate patients when they are shown the post-treatment results.[9]

Orthognathic surgery decision-making

In certain borderline cases, an orthodontist may have to make a decision on borderline cases, whether to opt for surgery first approach or attempt a camouflage with extractions or more recently TADS. Most of the decisions are based out of lateral cephalometric evaluation of landmarks; a combination of AI and machine learning has shown a 90% accuracy in identifying the Orthognathic surgery decision. 3DMM or 3D morphable models are simulations that can help in diagnosing and deciding the need for Orthognathic surgery. A neural network called Deep Pose has shown a 90% accuracy in predicting Orthognathic surgery needs as well as associated extraction treatment protocols.[8]

Remote patient monitoring

This involves using AI-based apps like Dental Monitoring (DM) which allow the patient to click photos of their intraoral cavity using their smartphone. The data can be accessed by the orthodontist to monitor any setbacks or problems the patients can encounter during treatment. The DM app needs to be installed on both the patient's and clinician's phones, An AI algorithm and a cloud-based storage called the Doctor Dashboard allow for remote monitoring.[10]

The Deep Learning AI uses a large dataset to detect ideal attributes during the treatment and it can also identify subsequent appointment progress etc. through a strong neural network. A recent study revealed that using artificial intelligence for remote monitoring gas reduced the number of patient appointments/clinic visits. This gives patients increased flexibility, especially in orthodontic treatment where monthly visits are necessary to track progress. This reduces the chairside time of the orthodontist and improves patient convenience with the overall treatment.[10]

Some possibilities of remote monitoring include.

- In Clear Aligner treatment
  - Fracture of Aligner
  - Loss of any attachments/buttons
  - Gingival recession/inflammation
  - Poor oral hygiene
  - Ill-fitting aligners/ loss of tracking
  - Reduced visits
  - Incomplete seating of aligner
  - Long-distance orthodontic treatment
- Fixed appliances
  - Adverse effects of treatment (soft tissue injuries/ wire extensions)

  - Noticing passive arch-wires
  - Oral hygiene maintenance
  - Awaiting tooth eruption in mixed dentition
  - Identifying bracket/wire breakages
  - Monitoring expansion status (RME/ MARPE)
- Post-treatment monitoring
  - Retainer wear
  - Stability and relapse
  - Fixed retainer breakages if any

Fig.11: remote patient monitoring using Dental Monitoring.

Drawbacks of AI in orthodontic treatment[11]

Fig.12: AI drawbacks flowchart.

REFERENCES

1. Retrouvey JM. The role of AI and machine learning in contemporary orthodontics.
2. Monill-González A, Rovira-Calatayud L, d'Oliveira NG, Ustrell-Torrent JM. Artificial intelligence in orthodontics: Where are we now? A scoping review. Orthodontics & Craniofacial Research, 2021 Dec; 24: 6-15.
3. Leonardi R, Giudice AL, Isola G, Spampinato C. Deep learning and computer vision: two promising pillars, powering the future in orthodontics. Semin Orthod, 2021; 27(1): 2021.
4. Retrouvey JM, Conley RS. Decoding Deep Learning applications for diagnosis and treatment planning. Dental Press J Orthod, 2022; 27(5): e22spe5.
5. Mehta S, Suhail Y, Nelson J, Upadhyay M. Artificial Intelligence for radiographic image analysis. Seminars in Orthodontic, 2021 Jun 1 (Vol. 27, No. 2, pp. 109-120). WB Saunders.
6. Felicia Miranda, Selene Barone, Maxime Gillot, Baptiste Baquero, Luc Anchling, Nathan Hutin, Marcela Gurgel, Najla Al Turkestani, Yanjie Huang, Camila Massaro, Daniela Garib, Antonio Ruellas, Karine Evangelista, Aron Aliaga-Del Castillo, Marilia Yatabe, Hina Shah, Jonas Bianchi, Juan Carlos Prieto & Lucia Cevidanes (2023) Artificial Intelligence Applications in Orthodontics, Journal of the California Dental Association, 51: 1, 2195585
7. Bianchi J, Ruellas A, Prieto JC, Li T, Soroushmehr R, Najarian K, Gryak J, Deleat-Besson R, Le C, Yatabe M, Gurgel M. Decision support systems in temporomandibular joint osteoarthritis: a review of data science and artificial intelligence applications. InSeminars in orthodontics, 2021 Jun 1 (Vol. 27, No. 2, pp. 78-86). WB Saunders.
8. Kazimierczak N, Kazimierczak W, Serafin Z, Nowicki P, Nożewski J, Janiszewska-Olszowska J. AI in orthodontics: Revolutionizing diagnostics and treatment planning—A comprehensive review. Journal of Clinical Medicine, 2024 Jan 7; 13(2): 344.
9. Park JH, Kim YJ, Kim J, Kim J, Kim IH, Kim N, Vaid NR, Kook YA. Use of artificial intelligence to predict outcomes of nonextraction treatment of Class II malocclusions. InSeminars in Orthodontics, 2021 Jun 1 (Vol. 27, No. 2, pp. 87-95). WB Saunders.
10. Hansa I, Katyal V, Semaan SJ, Coyne R, Vaid NR. Artificial Intelligence Driven Remote Monitoring of orthodontic patients: clinical applicability and rationale. InSeminars in Orthodontics, 2021 Jun 1 (Vol. 27, No. 2, pp. 138-156). WB Saunders.
11. Lee MK, Allareddy V, Rampa S, Elnagar MH, Oubaidin M, Yadav S, Rengasamy S. Applications and challenges of implementing artificial intelligence in orthodontics: A primer for orthodontists. InSeminars in Orthodontics, 2024 Jan 10. WB Saunders.