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Artificial Intelligence – Current Perspective In Orthodontics

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Abstract

In Recent years, artificial intelligence (AI) technology has become a revolutionary tool in health care system. Among various other fields, Increase in application of the technology noted significantly in Orthodontics as well. AI adjuncts to help orthodontists as it can be utilized from the beginning of diagnosis to treatment planning, also to predict outcomes. Along with faster diagnosis and treatment processes, automation can cut labour expenses to zero and increase precision. A well-trained AI model, which simulates human intelligence through machines, can aid in linear, angular, and volumetric measurements, greatly reducing measurement time so that researchers can focus their efforts on discovering novel clinical insights. In this article, artificial intelligence in orthodontics is discussed in relation to its use to clinical decision -making, diagnosis and treatment planning, estimation of growth and development, evaluating the facial proportion, prediction of cephalometric land mark and force system and also in analysing the soft tissue treatment outcomes, appliance printing, for referral, monitoring progress.

Keywords: Artificial intelligence, Orthodontics, Efficiency.

Introduction

The use of information technology (IT) in the dental field has increased drastically over the past 25 years and has helped to reduce cost, time, dependence on human expertise, and medical errors. AI's main objective is to offer a machine the ability to have its own intelligence. Put another way, AI aims for a machine to be able to learn through data, to solve problems by itself. John McCarthy first used the term "artificial intelligence" in 1956[1].

Machine learning (ML) is the integral part of AI. It depends on algorithms to predict outcomes based on large data sets and draws influence from many research disciplines[1]. Deep learning is inherent part of ML, using networks with different computer layers, called Artificial neural networks (ANNs) similar to human brain to

analyse input data. Its purpose is to build a neural network that can automatically recognize patterns to facilitate data-driven decision[2,3].

Recently, AI role in orthodontics like Diagnosis and treatment planning, Estimation of growth and development, Cephalometrics, 3D printing, simulation, predicting treatment outcome has become significant.

This article aims to determine the applications of AI that are extensively employed in the field of orthodontics, to evaluate the benefits of AI and to discuss its potential implications in this speciality.

Application of AI in Orthodontics

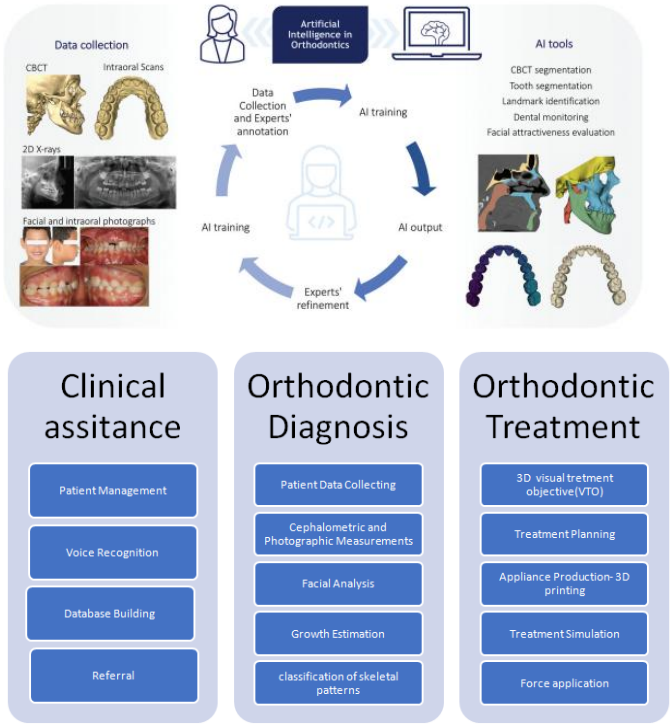

Fig. 1: Sequence of development of AI tools in orthodontics[15].

Diagnosis and treatment planning

The foundation for a correct and accurate orthodontic diagnosis relies on patient information that has been carefully gathered from a various database that includes a brief description of the patient's issues[3]. Contemporary orthodontic diagnostic aids include Written or verbal interview information, clinical examination, and review of patient records, including dental analysis, facial analysis, Radiographs, prediction of growth, airway patency can all be used to construct the orthodontic diagnostic database to evaluate patients malocclusion[3] . These process of diagnosis and imaging progressing to automation has improved evaluation speed and accuracy. With the use of digital dentistry tools, patient information can now be gathered on a digital platform and turned into a database that can be utilised for both diagnosis and treatment. The evaluation burden has been significantly reduced and diagnostic variations have been avoided thanks to automation solutions that use AI and machine learning technology[4].

Work flow of AI in Diagnosis and treatment planning

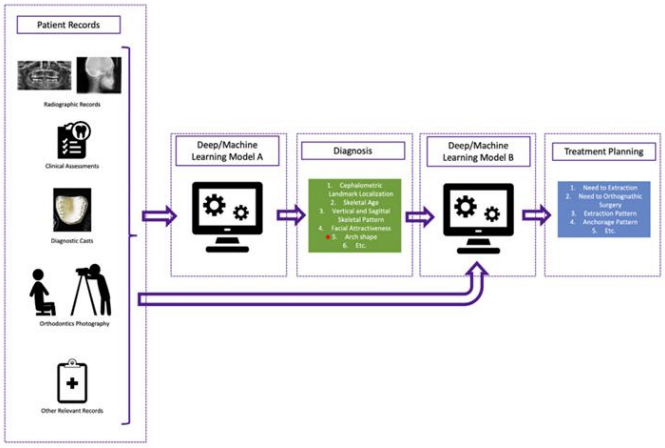

Fig. 2: work flow of AI in diagnosis and treatmentplanning[5]

Assessment of Orthodontic treatment need:

In a study in 2021 by Talat et al ,assessing the validity of using Convolutional Neural Network (CNN) digital model to detect and localize orthodontic malocclusions from intraoral clinical images, identifying malocclusion like crowding, spacing, increased overjet, cross bite, open bite, deep bite. The built AI engine accurately detected and localized malocclusion from different views of intra-oral clinical images, proved valid[10].

Segmentation and landmark identification

Automated identification of landmarks on lateral cephalogram and cone-beam computed tomography (CBCT) scans can save time for the clinicians and act as a second set of eyes for analysis of radiographic images in diagnosis and treatment planning[6]. Several machine-learning techniques have been utilized for this purpose with varying accuracies. However, high degree of variability in the clinical presentation of orthodontic patients, limitations of the algorithms, lack of labelled data, high compute power, etc. are some drawbacks that have limited robust clinical application of such techniques. In recent years, artificial neural networks like deep learning and more specifically deep neural networks are making significant inroads in the true adoption of this technology. YOLOv3 and Single Shot Multibox Detector are some of the deep learning algorithms that have shown reliable[9]. Deep convolutional neural network-based analysis for automated cephalometric tracing was used by Lee et al. (2020). The programme developed has a high success rate (over 90%), according to the authors, in the differential diagnosis of cephalometric landmarks[11].

Cephalometrics

In Automated lateral cephalometric analysis the shortcomings of accuracy has to be ameliorated. Currently, AI-based cephalogram are replacing manual tracing and identification of land marks by saving time and minimizing errors[12]. Kunz et al., (2020) analyzed the accuracy of their AI for automated cephalometric analysis based on commonly used orthodontic parameters[7,8]. The authors were able to show that, out of twelve different orthodontic parameters (including skeletal sagittal, skeletal vertical, and dental parameters), only one parameter was found to be significantly different compared to the human gold standard. , Schwendicke et al.(2021), pointed out that there was an increased risk of bias in the majority of studies investigating the use of AI for the automated analysis of cephalometric images. This fact should be viewed critically as some commercial providers already offer such software solutions for which the underlying scientific data for the AI are inadequately communicated, unclear, or lacking[9]. Automated cephalometric tracing was subsequently investigated by a number of other researchersand found that there are major differences concerning the assessment qualities of those different providers, and most authors, therefore, concluded that fully automated cephalometric analyses should only be used with human supervision by experienced clinicians[7.]

Estimation of growth and development

Timing is a significant entity to be considered in orthodontic diagnosis and treatment planning. Anthropometric indications such as chronological age, dental age, menarche, voice changes, height gain, and skeletal maturation can be used to determine growth and development (skeletal age) and radiography such as CVM and hand wrist radiographs even index finger X-rays, are frequently utilised as input data base to find signs of skeletal maturation[13]. AI systems can evaluate these Input with deep learning ability and now the estimation of age by the application of Machine learning algorithm and AI technologies is automated precisely with a performance like a radiologist. However, growth dynamics during adolescence differ greatly among individuals, making it insufficient to rely solely on chronological age for estimating the amount of remaining growth[14] .

Facial proportions

Measuring ratios and the linear distances between facial structures are part of the evaluation of facial proportions.

Lateral cephalographs and profile pictures have been used to evaluate the same but due to the variations in magnification, sensitive measurements there are operator sensitivity[16] .The greatest advancement in bringing human perception closer to the machine has been in the development of computer vision techniques. These techniques have a variety of dimensions and are significant in many respects. One of the explicit dimensions, features, in various studies examined from 4 directions. In the first type of feature, geometrics and holistics are separated (e.g., hairstyle or skin color). Due to the possibility for holistic measurements to change with aging and makeup, geometric measurements are more reliable (L. Zhang, Zhang, Sun & Chen, 2017). The second type of feature, upon which landmark models are built, shows that adding landmarks increases the accuracy of the results (Chen, Xu, Zhang &Chen, 2015). There is an automated feature extraction system that continuously aids in results since these days, most studies require manual correction of a few points, and the last is the effect of each feature on the conclusion, which is considered to be the same in many studies (Dornaika et al., 2020). The type of neural network is also important since supervised and semi-supervised neural networks have been heavily used in recent years[17].

As the facial beauty is a very subjective concept and there is no validated set of rules for facial aesthetics. However, the classical rules of ideal facial aesthetics have some deficiencies in reflecting the beauty perception of the population. Currently, optical facial recognition has been performed by AI applications and they are also simulate much complex cognitive tasks including analysis and interpretation of facial data. Studies in this field showed that AI systems seemed to be promising tools to build a validated formula for the human perception of facial attractiveness[18].

Decision Support for Orthodontic Extractions

The two main reasons for tooth extraction in orthodontics are as follows:

1. Need for Space to Align the Teeth in the Presence of Severe Crowding
2. In order to remedy the protrusion or conceal the skeletal Class II or Class III issues, the teeth may be repositioned (often to retract the incisors)[19].

A decision-making expert system (ES) was created by Xie et al (2010). to determine if extraction is necessary for patients between the ages of 11 and 15 years as a part of orthodontic treatment. According to this study, identifying the need for extraction or non-extraction treatment withthe indices as "anterior teeth uncovered by incompetent lips" and "IMPA (L1-MP)" should be taken into consideration as extraction . The result had an accuracy rate of 80%.,here ANN uses the error backward propagation learning technique to reduce the likelihood of error[19].

With an accuracy of 84%, Jung et al. employed the ANN to predict the specific extraction patterns. Li P et al, used ANN to accurately predict the need for anchorage in extraction cases 83% of the time. To forecast treatment plans, ascertain whether or not extraction is necessary, ascertain the pattern of extraction, and ascertain anchoring, Kong et al. deployed an artificial neural network with a multilayer perceptron. The findings revealed accuracy of 94% for predictions of extraction and non-extraction, 84.2% for patterns of extraction, and 92.8% for patterns of anchoring. Crowding, upper arch, ANB, and Spee's curve are the most crucial characteristics for prediction[20]. Results shows that the neural network can be utilised to guide less experienced orthodontists during treatment[19,20]

Management of impacted canine

To achieve the best orthodontic, esthetic and periodontal results, impacted canines require extensive therapeutic care. An intermediary stance between statistics and artificial intelligence is taken by the Bayesian Network (BN)[21]. Based on the angular and linear measurements, OPG and lateral cephalometric radiographs, CBCT are helpful in predicting an impacted maxillary canine. The random forest method had the best degree of accuracy and correctly predicted the canine eruption condition (83%). In cases with unilateral canine impaction, Wang et al used CBCT and a machine learning technique called Learning-based multisource Integration framework for Segmentation (LINKS) to quantify the variance in the maxilla[22].

Study also suggests that palatal expansion could be beneficial for those with unilateral canine impaction, as underdevelopment of the maxilla often accompanies that condition in the early teen years. Fast and efficient CBCT image segmentation will allow large clinical data sets to be analyzed effectively with AI [22].

Force system analysis

The applied force and tissue response brings tooth movement and orthopaedic changes, and these force systems have been investigated using static systems for simple springs. An artificial neural network was employed in a study by Kazem et al. to analyse the force system of T-retraction springs and was successful in input-output mapping[23].

Appliance selection

Head gear: Headgear, an orthopaedic appliance which acts by restraining the maxillary growth through extraoral traction. There are three types – high, medium, and low pull headgears. A computer assisted inference model has been developed by Akgam et al. in order to select a right type of headgear according to the clinical situation and this would help a less experienced orthodontist in decision making to choose a right type of headgear, the study concludes the usefulness of the proposed inference logic[24].

In treatment Prediction

Soft tissue outcome: Evaluation of soft tissue profile has been considered as an important part in orthodontic diagnosis and treatment planning. Hence orthodontist must pay attention towards the relationship of nose, lips and chin during the orthodontic extractions. According to a study by Nanda SB et al., a significant change has been noticed on the curvature of upper lip was noted with extraction and non-extraction treatment. Study proved that ANN models are more effective in predicting the changes with extraction and non - extraction cases[25]. AI tools, allow us to implement facial features beyond symmetry and proportionality and incorporate facial analysis into diagnosis and treatment planning in orthodontics.[26]

AI in temporomandibular joint disease

Orthopantomogram (OPG) is first line of examination tool for assessing bony changes in TMJ and if required CBCT may be used for confirming the diagnosis. But sometimes in the absence of an expert, patient's TMJ arthritis or other bony changes may misread. To eliminate this problem an AI algorithm was developed and trained to read TMJ osteoarthritis on OPGs [27].

AI for referral

A artificial intelligence expert system called the Computational Formulation of Orthodontic referral Decisions (CFOD) was created in order to provide decision-making for orthodontic diagnosis and referral in the Emirates public oral healthcare system. The CFOD system was implemented A comparison of referral patterns of orthodontic patients before and after implementation and training of the CFOD system

demonstrated a 10-fold increase for GP referrals and 2-fold for pediatric dentist referrals[28].

Tracking tooth movements

Dental Monitoring (DM; Paris, France) Artificial Intelligence Driven Remote Monitoring technology was conducted in which AI tracking algorithm can track tooth movement and reconstruct 3D digital models to a clinically acceptable degree for orthodontic application.[29]

AI driven OHI

The oral hygiene of orthodontic patients rapidly worsens over the first 3 months and plateaus after about 5 months of treatment. Artificial Intelligence Driven Remote Monitoring Technology (AIDRM) with weekly Dental Monitoring™ (DM™) scans and personalized active notifications through smart phones may improve oral hygiene over time in orthodontic patients[30].

AI in orthognathic surgery

The AI has been integrated into robotic operations across various medical specialties, including neurological, gynaecological, cardiothoracic, and other general surgical procedures. The incorporation of AI in these robotic surgeries enhances precision, efficiency, and decision- making, leading to improved surgical outcomes in diverse medical fields.[31]

Future Perspectives of AI

The process is not one-way; the accuracy of the predictions can be used as feedback to improve the initial model and feature engineering, creating a constructive feedback loop for continuous enhancement. In the context of orthodontics, precision medicine involves a more comprehensive diagnostic procedure, individualised treatment plans, and advanced treatment processes.[32] This approach aims to provide more effective therapy with fewer side effects and shorter treatment times, tailored to each patient's unique needs. The application and advancement of AI technology in dentistry and orthodontics hold the potential to improve medical quality while simultaneously reducing expenses. This exciting development paves the way for more precise, efficient, and patient-centric healthcare, benefiting both dental professionals and patients alike

Conclusion

In the fields of medicine and dentistry, artificial intelligence (AI) has expanded dramatically and now it has been gaining popularity in the field of orthodontics as a powerful problem-solving tool by assisting in diagnosis, treatment planning and prediction of cephalometric landmarks etc. Efficiency, accuracy, precision, reduced effort, time savings, and better monitoring is all benefits of AI towards utopia. But AI should be assessed and applied carefully in order to avoid any misleading information. Though, AI is heading towards success still it cannot replace an expert clinician in near future.

References

1. Asiri SN, Tadlock LP, Schneiderman E, Buschang PH. Applications of artificial intelligence and machine learning in orthodontics. APOS Trends Orthod. 2020;10(1):17–24.
2. Hung HC, Wang YC, Yu-Chih W. Applications of Artificial Intelligence in Orthodontics. Taiwanese J Orthod. 2020;32(2):3–3.
3. JunqiLiu ,Chengfei Zhang and Zhiyi Shan . Application of Artificial Intelligence in Orthodontics: Current State and Future Perspectives, Healthcare 2023, 11, 2760.
4. Ahmed N, Chethana, Younus A A, Aymen U, Rahul NA. Artificial intelligence in orthodontics: A way towards modernization. IP Indian J Orthod Dentofacial Res 2023;9(1):3-7.

5. Mohammad-Rahimi H, Nadimi M, Rohban MH, Shamsoddin E, Lee VY, Motamedian SR, et al. Machine learning and orthodontics, current trends and the future opportunities: A scoping review. Am J Orthod Dentofacial Orthop. 2021;160(2):170–92.
6. Shivam Mehta,Yasir Suhail et al , Artificial Intelligence for Radiographic image analysis. Seminars in Orthodontics. 2021 Vol 27, Issue 2, P-109-120.
7. Felix Kunz , Angelika Stellzig-Eisenhauer and Julian Boldt. Applications of Artificial Intelligence in Orthodontics—An Overview and Perspective Based on the Current State of the Art.
8. Kunz, F.; Stellzig-Eisenhauer, A.; Zeman, F.; Boldt, J. Artificial intelligence in orthodontics: Evaluation of a fully automated cephalometric analysis using a customized convolutional neural network. J. Orofac. Orthop. 2020, 81, 52–68.
9. Schwendicke, F.; Chaurasia, A.; Arsiwala, L.; Lee, J.H.; Elhennawy, K.; Jost-Brinkmann, P.G.; Demarco, F.; Krois, J. Deep learning for cephalometric landmark detection: Systematic review and meta-analysis. Clin. Oral Investig. 2021, 25, 4299–4309.
10. The Validity of an artificial intelligence application for assessment of orthodontic treatment need from clinical images. Seminars in Orthodontics. 2021 Vol 27, Issue 2 , P-164-171.
11. Subramanian AK, Chen Y, Almalki A, Sivamurthy G, Kafle D. Cephalometric Analysis in Orthodontics Using Artificial Intelligence-A Comprehensive Review. BioMed Res Int. 2022.
12. Khanagar SB, Al-Ehaideb A, Vishwanathaiah S, Maganur PC, Patil S, Naik S, et al. Scope and performance of artificial intelligence technology in orthodontic diagnosis, treatment planning, and clinical decision-making - A systematic review. J Dent Sci. 2021;16(1):482– 92.
13. Lee H, Tajmir S, Lee J, Zissen M, Yeshiwas BA, Alkasab TK, et al. Fully automated deep learning system for bone age assessment. J Digit Imaging. 2017;30(4):427–41.
14. Khanagar S.B., Al-Ehaideb A., Vishwanathaiah S., Maganur P.C., Patil S., Naik S., Baeshen H.A., Sarode S.S. Scope and Performance of Artificial Intelligence Technology in Orthodontic Diagnosis, Treatment Planning, and Clinical Decision-Making—A Systematic Review. *J. Dent. Sci.* 2021; 16:482–492.
15. Miranda ,Barone, Gillot et al , Artificial intelligence applications in orthodontics , journal of California denta;l association , 2023 vol51, p 1-13.
16. Nausheer Ahmed et al,Artificial intelligence in orthodontics: A way towards modernization IJODR, 2023;9(1):3–7.
17. Moridani,Jamiee et al.Human -like evaluation by facial attractiveness intelligent machine . International journal of cognitive computing in engineering 2023 vol 4, p-160-169.
18. Patcas R, Bernini DAJ, Volokitin A, Agustsson E, Rothe R, Timofte R, et al. Applying artificial intelligence to assess the impact of orthognathic treatment on facial attractiveness and estimated age. Int J Oral Maxillofac Surg. 2019;48(1):77–83.
19. Xie X, Wang L, Wang A. Artificial neural network modeling for deciding if extractions are necessary prior to orthodontic treatment. Angle Orthod. 2010;80(2):262–6.
20. Jung SK, Kim TW. New approach for the diagnosis of extractions with neural network machine learning. Am J Orthod Dentofacial Orthop. 2016;149(1):127–33.

21. Bahaa K, Noor G, Yousif Y. The artificial intelligence approach for diagnosis, treatment and modelling in orthodontic. Principles ContempOrthod. 2011;p. 451.
22. Si Chen ,li Wang et al.Machine Learning in Orthodontics :Introducing a 3-D Auto segmentation and auto landmark finder of CBCT images to assess maxillary constriction in unilateral impacted canine patients Angle ortho . 2020 Jan:90(1);77-84.
23. Kazem BI, Ghaib NH, Grama NM. Experimental investigation and neural network modeling for force system of retraction T-spring for orthodontic treatment. J Med Device. 2010;4(2).
24. Akçam MO, Takada K. Fuzzy modelling for selecting headgear types. Eur J Orthod. 2002;24(1):99–10.
25. Nanda SB, Kalha AS, Jena AK. Artificial neural network (ANN) modeling and analysis for the prediction of change in the lip curvature following extraction and non-extraction orthodontic treatment. J Dent Spec. 2015;3(2):130–9.
26. Tomasil ,Marton et al.AI and face-driven Orthodontics :A scoping review of Digital advances in diagnosis and treatment planning .MDPI, 2024 , *5*(1), 158-176.
27. Choi E, Kim D, Lee JY, Park HK. Artificial intelligence in detecting temporomandibular joint osteoarthritis on orthopantomogram. Sci Rep. 2021;11:10246.
28. Mohamed,Ferguson et al , An artificial intelligence based referral application to optimise orthodontic referrals in a Public oral healthcare system . Seminars in Orthodontics. 2021 Vol 27, Issue 2, P-157-163.
29. Homsi,Snider,Kusnoto et al .Intellignece driven remote monitoring technology for tracking tooth movement and reconstruction of 3-Dimensional digital models during orthodontic treatment .AJODO.2023.Vol 164, Issue 5, p-690-699.
30. Snider, Homsi, ,Kusnoto et al. Effectiveness of AI - driven remote monitoring technology in improving oral hygiene during orthodontic treatment .Orthodcraniofac Res 2023 suppl 1;102-110.
31. P. Bouletreau, M. Makaremi et al, Artificial Intelligence: Applications in orthognathic surgery. J Stomatol Oral Maxillofac Surg,2019,707.
32. Sharma, Jadhav, Bhuskute et al, Artificial intelligence :An innovative approach in orthodontics :A narrative review. Journal of Clinical and Diagnostic Research. 2023 Dec, Vol-17(12): ZE07-ZE11.