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Review Article

Dentistry Section

Artificial Intelligence: An Innovative Approach in Orthodontics: A Narrative Review

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ABSTRACT

The present article aims to describe how Artificial Intelligence (AI) assists orthodontics with its potent algorithms for identification and prediction, aiding medical professionals in making better treatment choices. AI is a valuable tool for helping orthodontists determine the best approach for moving teeth with orthodontic appliances to predetermined positions. Symbolic AI, an expertise system based on human comprehension of a problem, organises knowledge into algorithmic structures. While it remains applicable for problem-solving with limited potential outcomes and the need for human explainability, building rule-based models in complex healthcare scenarios with multiple explanatory variables proves exceptionally challenging, if not impossible. However, modern AI often overlooks oral disorders, fails to fully incorporate facial analysis into its models, and neglects functional issues when developing remedies. Nonetheless, AI does improve imaging, diagnosis, specificity, and more in various situations, from identifying syndromes to detecting caries. Orthodontic diagnosis is complex, involving the simultaneous assessment of multiple facial features from different perspectives. Digital dentistry tools and AI-driven automation solutions have streamlined the process by digitally recording patient history and reducing diagnostic variations, benefiting both diagnosis and treatment. With its problem-solving capabilities, AI is starting to provide orthodontists with more powerful resources to deliver higher standards of care. AI-based technology can be utilised to gain new insights from various types of medical data. The present article aims to provide a concise overview of the use of AI in orthodontic care. The literature review is divided into six categories: extraction or non extraction therapy in orthodontic treatment, orthognathic surgery, segmentation and landmark identification, growth prediction, cleft-related studies, and Temporomandibular Disorders (TMD) classification.

Keywords: Computer-assisted, Diagnoses, Learning, Machine, Orthognathic, Surgeries

INTRODUCTION

The face is at the centre of orthodontic science and art, and our ability to manage its growth is crucial. Orthodontists manipulate the craniofacial skeleton to achieve their goals, focusing particularly on the dentoalveolar region, the Temporomandibular Joint (TMJ), and the sutures [1]. Some individuals receive external orthopaedic forces similar to certain medical orthopaedic methods. However, most treatments focus on altering the occlusion, regulating dentoalveolar development, and preventing abnormal vertical growth. Over the past 25 years, there has been a significant increase in the adoption of Information Technology (IT) within the orthodontic industry. This adoption has led to reduced time, cost, reliance on humans, and occurrences of dental mishaps. AI, a branch of computer science, consists of software and hardware that can observe its surroundings and take actions to improve its chances of success [2,3]. The term AI was first coined by John McCarthy and officially recognised by Dartmouth College in 1956, although developments in AI had begun in 1943. Medical data can be analysed, organised, represented, and catalogued using AI. It has effective pattern recognition and prediction algorithms, which are advanced scientific approaches in various fields [4].

By 2024, the global market for AI in healthcare is expected to grow from $1.3 billion to $10 billion, according to a 2019 Morgan Stanley forecast [5]. AI pertains to the behaviours exhibited by non biological entities in complex scenarios [6]. It refers to the capacity of a system to emulate a machine with human-like intelligence, capable of logical reasoning, critical thinking, and making optimal decisions [7]. AI is a collection of problem-solving tools, each with its own unique set of rules, rather than a computer tool that tries to replicate the operations of the human brain [4]. In the era of AI, researchers are striving to achieve a level of generalisation comparable to that of humans [8]. However, most AI advancements have been made with models that focus on specific problem conditions and have a limited set of instructions-problems like detecting cavities through X-ray images [9]. Computer solutions outperform human ones for many of these issues. While there are many other classifications of AI, two primary types are symbolic AI and Machine Learning (ML) from an algorithmic standpoint [10]. AI finds applications in diverse fields, including Deep Learning (DL), Convolutional Neural Networks (CNNs), ML, Artificial Neural Networks (ANNs), and even in biological and medical diagnostics [11].

Symbolic Artificial Intelligence (AI)

The foundation of symbolic AI technique is to create the algorithm in a form that is understandable to humans [3]. It is commonly used for solving problems where there are few viable solutions, a shortage of computing capacity, or human explanation is crucial [8]. Symbolic AI represents an expertise system that operates within the boundaries of current human comprehension of the problem, organising this knowledge into algorithmic structures. Symbolic AI continues to be utilised for problem-solving scenarios with constrained potential outcomes, scarcity of computational power, or the necessity for human explainability [8]. However, in the healthcare sector, where issues are frequently intricate, not fully comprehended, and involve multiple explanatory variables, building a rule-based model is exceedingly difficult, if not entirely impossible [8].

Machine Learning (ML)

Arthur Samuel introduced the concept of Machine Learning (ML) in 1952, which is the widely utilised technique today. In dentistry and the medical field, ML is the most commonly employed application of AI. The primary distinction between ML and symbolic AI lies in their learning approaches. In ML, models acquire knowledge from examples, while in symbolic AI, knowledge is represented through a set of predefined rules implemented by humans [4]. Machines can enhance their performance by learning from previous models when new data is introduced, using a combination of statistical and probabilistic tools [4]. This can involve making predictions, identifying novel patterns, or classifying new data. Based on the learning style used by the algorithm and the desired outcome, ML can be divided into three categories: supervised learning, used for classification or prediction based on known outcomes; unsupervised learning, which discovers hidden patterns and structures with unknown outcomes; and reinforcement learning, where the machine develops an adaptive algorithm based on previous iterations to maximise the intended reward [12]. A branch of ML called DL uses the computers to calculate specific aspects of an input. DL's predecessor is an ANN that came in practice since the 1900s. As computer technology and processing power have significantly advanced, researchers have developed increasingly complex and "deeper" neural networks to tackle more complex clinical challenges. The term "DL" has been assigned to these neural networks [13].

Empowering Orthodontics with Artificial Intelligence (AI)

In both dentistry as a whole and specifically in orthodontics, AI has been applied to address various challenges. The initial efforts to utilise AI in orthodontics involved knowledge-based Expert Systems (ES). These systems primarily aimed to assist non specialised dentists in developing diagnosis and treatment plans [14-17]. Particularly in foreign countries, where hospital-based orthodontists faced extensive waiting lists and a higher patient load compared to their counterparts in Europe and the United States, these ESs proved beneficial [18]. As there was a decrease in the prevalence of caries during that period, dentists could treat less complex cases identified by the ESs while referring more intricate cases to orthodontists. However, these early systems had limitations. They were only effective with cases already stored in the system and struggled to handle new and more complex cases. Nowadays, dentistry has access to much more advanced ML systems, which can diagnose a broader range of orthodontic cases and define treatment needs [18].

Genetic disorders sometimes have better outcomes when they are diagnosed early. Likewise, because many syndromes have recognisable facial traits, craniofacial phenotypes are extremely instructive for determining accurate analysis of hereditary illnesses [4]. These morphological changes to the face are frequently of great orthodontic interest. Numerous syndromes cause malocclusions and dentofacial abnormalities that need to be corrected with orthodontics. Various modified systems have been developed to aid orthodontists in diagnosing and planning treatments, as well as evaluating treatment outcomes and growth.

1. **Planning tooth motion using Machine Learning (ML):** It seems that employing AI to aid in the planning of orthodontic treatment has been a reality for a long time. Once an orthodontist tells the machine where the end position should be, AI is a great tool to assist in choosing the optimum approach for tooth movement [4]. This is helpful since traditional orthodontics, which uses just brackets, requires a high level of manual ability that many practitioners lack or do not have due to inadequate training. Although AI helps these dentists, ML has several limits when used in modern aligner therapy [4]. The occurrence of dental diseases and any prior medical treatments that may have an impact on the recommendation of orthodontic adjustments, whether with aligners or fixed equipment, are completely ignored by AI today. Since pathological tooth migration is a typical side effect of periodontitis, patients with the disease appear to be more interested in having their teeth straightened [19-21]. However, orthodontic treatment should not be done when a disease is active. Therefore, it is required that an orthodontist conduct a thorough anamnesis, examine the patient, make a diagnosis, and then prescribe the appropriate therapy before implementing it [22]. Orthodontics is frequently carried out following necessary endodontic, periodontal, restorative, etc., procedures. This makes the use of AI technology extremely risky. Another drawback is that current AI algorithms do not take into account facial analysis, proportions, and aesthetics of patients. Orthodontic dental movements and facial aesthetics have a direct relationship. These evaluations can only be carried out by a skilled orthodontist as the movement of teeth in any direction affects facial and smile aesthetics [23]. Additionally, facial analysis is the initial stage in identifying the presence of dentofacial abnormalities and, consequently, the potential for surgical orthodontic treatments [24]. Aligners, for instance, can be used to correct issues caused by significant functional aetiologies like open bite malocclusion [25]. However, AI is currently unable to identify the root cause of the issue or predict specific retention tactics. As a result, treatment options such as skeletal anchoring, teeth extractions, and integrated restorative operations are limited. Furthermore, AI algorithms do not successfully incorporate numerous orthodontic techniques. This is caused, atleast in part, by the inability of aligners to control certain tooth movements due to mechanical issues. Additionally, from the perspective of the doctor, brackets, wires, and other attachments were devised to enhance the user experience. However, orthodontic management and appliances must be tailored according to the patients' needs [26]. Consequently, a major challenge in modern orthodontics is that if the conventional bracket device is not optimal due to aesthetic and comfort issues, then aligners won't be either due to mechanical issues. Therefore, it still requires a lot of work to create a device design that takes into account all of these factors.
2. **Pioneering the future of diagnosis and treatment planning using AI:** Orthodontic diagnosis is a challenging task as it requires a comprehensive and simultaneous assessment of multiple facial features viewed from various perspectives. With the help of the implementation of digital dentistry tools, the patient's history can be recorded digitally and transformed into digital storage that serves both diagnostic and treatment purposes. The use of AI and ML technology in automation solutions has significantly alleviated the evaluation burden and eliminated diagnostic variations [4,27].
3. **Image analysis using Machine Learning (ML):** AI has steadily been used in imaging diagnosis to improve specificity and sensitivity, i.e., the ability to accurately forecast the presence of an illness or issue in patients and the ability to eliminate the disease or problem when the person doesn't have it. Due to how easily the computer interacts with patterns, AI has great potential in imaging diagnosis [28]. ML has also made a significant impact on X-ray analysis, which plays a significant role in orthodontic diagnosis and treatment planning. One key application of ML in orthodontics has been the recognition of landmarks in X-rays. Additionally, ML has been utilised to automate diagnostics straight from cephalometric investigations, involving assessing the sagittal relationships within the upper and lower jaw, along with the determination of normal and abnormal posterior-anterior facial height ratios, overbite, and overjet [29].

Furthermore, the use of panoramic radiographs in orthodontics poses a legal responsibility on orthodontists to accurately diagnose lesions or tumours [30]. To address this, an automated neural network system has been developed, capable of correctly diagnosing ameloblastomas and keratocystic odontogenic tumours from panoramic radiographs with an accuracy of 83.0% [30]. Furthermore, ML techniques have been harnessed with the objective of predicting occurrences of impaction in the maxillary canine. This is achieved through the utilisation of angular and linear measurements extracted from both panoramic and lateral cephalometric X-ray images [31]. These applications of ML enhance the orthodontists' ability to foresee potential impactions and plan treatment accordingly.

In medical imaging, such as X-rays, Computed Tomography (CT) scans, or Magnetic Resonance Imagings (MRI), image segmentation is performed to extract the pixels corresponding to target organs or lesions [32]. This segmentation process is vital for quantitative medical image analysis and the development of fully or partially automated computer-aided diagnosis systems. In the field of orthodontic therapy, landmark recognition from lateral cephalometric X-rays has been crucial for analysis and treatment planning for many years. To advance this process, Wang L et al., introduced a technique using Cone Beam Computed Tomography (CBCT) to program the segmentation of the maxilla and mandible [33]. The application of image segmentation techniques in medical imaging, combined with advancements like CBCT, offers great potential to improve accuracy, efficiency, and precision in diagnosing and planning treatments in various medical specialties, including orthodontics.

4. **Assessing growth and development and evaluating skeletal age:** In orthodontic diagnosis and treatment planning, timing holds significant importance. Anthropometric indicators, including chronological age, dental age, menarche, voice changes, height gain, and skeletal maturation, serve to assess growth and development (skeletal age). Radiography is commonly employed to identify signs of skeletal maturation [34]. Furthermore, the utilisation of X-ray analysis has been expanded to encompass hand and wrist radiographs for estimating skeletal age. Precisely determining the growth status of patients is crucial in making informed decisions regarding the inclusion of growth as a component of the treatment strategy [35].

5. **Extraction demands:** The prediction of extraction or non extraction therapy in orthodontic treatment planning is another intriguing contemporary application of AI [36]. The two primary reasons for creating space by extraction in orthodontics are:

   a. To create sufficient space for aligning teeth in cases of severe crowding.

   b. To address protrusion/correct skeletal Class-II or Class-III malocclusion by repositioning the teeth, frequently involving the retraction of anterior teeth [37].

   In 2016, Jung SK and Kim TW undertook a study focused on the contemporary employment of AI, specifically addressing the prognostication of tooth extractions within the context of orthodontic planning. The target teeth for extraction and the breadth of dentofacial alterations considered in the study were deliberately confined. This discretionary limitation likely mirrors the modest scale of the primary dataset. Nonetheless, this marks a propitious and invigorating initial advancement in the direction of ascertaining the necessity for incorporating extractions within the treatment regimen [36]. Xie X et al., developed a decision-making ES to assess the necessity of tooth extraction for malocclusion patients aged 11-15 years. An ANN was employed, utilising the error backward propagation learning technique, to minimise errors in the system. The study documented a precision rate of 80% in determining whether extraction is necessary or non extraction treatment would be sufficient [37]. Additionally, Jung SK and Kim TW achieved an accuracy of 84% by utilising ANN to forecast particular extraction patterns [36].

6. **Revolutionising Temporomandibular Joint (TMJ) disease diagnosis and treatment with AI:** The Orthopantomogram (OPG) is a widely used examination method to assess bony changes in the TMJ. If necessary, a CBCT can be utilised to validate its diagnosis. However, in the absence of an expert, there is a possibility of misreading TMJ arthritis or other bony changes in the patient [38]. To address this issue, AI is being utilised to identify and categorise TMJ osteoarthritis, potentially providing insights for developing targeted remedies tailored to the various degrees of the condition's severity [38].

7. **Unleashing the potential of orthognathic surgery and robotics in orthodontics with AI:** Orthognathic surgery is another area where AI is being used to diagnose and plan orthodontic therapy. Significant funding has been allocated to the research and development of digital orthodontics and three-dimensional modelling for orthognathic surgery [39]. Additionally, personalised surgical set-up planning and computerised treatment planning increase diagnostic accuracy, particularly for junior physicians [40]. Knoops PGM et al., formulated an ML paradigm aimed at the automated diagnosis and computer-assisted strategising within the domain of plastic and reconstructive surgery [41]. A surface 3D scan was employed to generate a large-scale clinical 3D Morphable Model (3DMM) using a supervised ML framework. Weichel F et al., and co-researchers established a computer-assisted planning apparatus grounded in the integration of CT scans, cephalometric data, and plaster models [42]. An intriguing study by Patcas R et al., evaluated effects of orthognathic procedures on facial desirability and age estimation using AI technology [43].

   The AI has been integrated into robotic operations across various medical specialties, including neurological, gynaecological, cardiothoracic, and other general surgical procedures [44]. The incorporation of AI in these robotic surgeries enhances precision, efficiency, and decision-making, leading to improved surgical outcomes in diverse medical fields. The prospective application of AI robotics in orthognathic surgery in the near future is highly promising. Robotic systems, being in direct contact with the patient, can potentially reduce infection rates. Moreover, the precision of jaw movement during surgery is expected to improve significantly. This shift towards precision medicine is transforming diagnostic and treatment approaches, moving away from the conventional "signs and symptoms" method to a more personalised approach [45,46].

   The process begins with deep phenotyping of the patient, which involves gathering extensive information on their genetics, biomarkers, lifestyle, and environmental factors, in addition to their clinical data. Data scientists then carry out feature engineering, exploratory data analysis, and data cleaning to extract valuable insights and patterns from the vast amount of data collected. The integration of AI robotics and precision medicine in orthognathic surgery holds great promise for enhancing patient outcomes, minimising complications, and revolutionising the field of maxillofacial surgery [47].

   As advancements in technology and medical knowledge continue, these innovative approaches are expected to play a crucial role in the future of orthognathic surgical procedures. The use of AI technologies allows dental professionals to create diagnostic and prognostic models based on vast amounts of "big data." These models can be utilised to forecast treatment outcomes with increased accuracy.

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. 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 [48].

CONCLUSION(S)

Orthodontic therapy has increasingly benefited from the use of AI technologies in numerous ways, demonstrating itself as a reliable and time-saving tool. In the future, the development of cloud-based systems for data sharing and integration could be pursued. Since data form the basis of well-built models, ML could produce more accurate predictions and image interpretations by utilising high-quality and large amounts of data. An appropriately trained AI model can assist with volumetric, linear, and angular measurements, as well as landmark detection in orthodontic research. Fully automated AI assessments can save a significant amount of time, allowing researchers to focus more on discovering novel insights from clinical evaluations.

REFERENCES

[1] Littlewood SJ, Mitchell L. An introduction to orthodontics. Oxford University Press; 2019. Pp. 408.
[2] Asiri SN, Tadlock LP, Schneiderman E, Buschang PH. Applications of artificial intelligence and machine learning in orthodontics. APOS. 2020;10(1):17-24.
[3] Haugeland J. Artificial intelligence: The very idea: (MIT Press, Cambridge, MA, 1985). 1986;29(3):349-53.
[4] Faber J, Faber C, Faber P. Artificial intelligence in orthodontics. APOS. 2019;9(4):201-05.
[5] Could artificial intelligence transform healthcare? Morgan Stanley. Available from: https://www.morganstanley.com/ideas/medtech-artificial-intelligence. [Last accessed on 2023 March 20].
[6] Dean TL, Allen J, Aloimonos J. Artificial intelligence: Theory and practice. Redwood City, Calif: Benjamin/Cummings Pub. Co; 1995. Pp. 563.
[7] Mohammad-Rahimi H, Nadimi M, Rohban MH, Shamsoddin E, Lee VY, Motamedian SR. Machine learning and orthodontics, current trends and the future opportunities: A scoping review. Am J Orthod Dentofacial Orthop. 2021;160(2):170-92.e4.
[8] Schwartz WB, Patil RS, Szolovits P. Artificial intelligence in medicine. Where do we stand? N Engl J Med. 1987;316(11):685-88.
[9] Hung M, Voss MW, Rosales MN, Li W, Su W, Xu J, et al. Application of machine learning for diagnostic prediction of root caries. Gerodontology. 2019;36(4):395-404.
[10] Hussain MA, Fatima S, Reddy KK, Ramya Y, Betha SP, Kauser A, et al. Artificial intelligence in orthodontics: A review. IJHS. 2022;(II):9378-83.
[11] 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.
[12] Bishop CM. Pattern recognition and machine learning. New York: Springer; 2006. pp. 738. (Information science and statistics).
[13] Bichu YM, Hansa I, Bichu AY, Premjani P, Flores-Mir C, Vaid NR. Applications of artificial intelligence and machine learning in orthodontics: A scoping review. Progress in Orthodontics. 2021;22(1):18.
[14] Brown ID, Adams SR, Stephens CD, Erritt SJ, Sims-Williams JH. The initial use of a computer-controlled expert system in the treatment planning of Class II division 1 malocclusion. Br J Orthod. 1991;18(1):01-07.
[15] Hammond RM, Freer TJ. Application of a case-based expert system to orthodontic diagnosis and treatment planning: A review of the literature. Aust Orthod J. 1996;14(3):150-53.
[16] Sims-Williams JH, Brown ID, Matthewman A, Stephens CD. A computer-controlled expert system for orthodontic advice. Br Dent J. 1987;163(5):161-66.
[17] Williams JS, Matthewman A, Brown D. An orthodontic expert system. Fuzzy Sets and Systems. 1989;30(2):121-33.
[18] Thanathornwong B. Bayesian-based decision support system for assessing the needs for orthodontic treatment. Healthc Inform Res. 2018;24(1):22-28.
[19] Tolman A, Jerrold L, Alarbi M. Squamous cell carcinoma of attached gingiva. Am J Orthod Dentofacial Orthop. 2007;132(3):378-81.
[20] Tanimoto Y, Miyawaki S, Imai M, Takeda R, Takano-Yamamoto T. Orthodontic treatment of a patient with an impacted maxillary second premolar and odontogenickeratocyst in the maxillary sinus. Angle Orthod. 2005;75(6):1077-83.
[21] Hyomoto M, Kawakami M, Inoue M, Kirita T. Clinical conditions for eruption of maxillary canines and mandibular premolars associated with dentigerous cysts. Am J Orthod Dentofacial Orthop. 2003;124(5):515-20.
[22] Kang BC, Yoon SJ, Lee JS, Al-Rawi W, Palomo JM. The use of cone beam computed tomography for the evaluation of pathology, developmental anomalies and traumatic injuries relevant to orthodontics. Seminars in Orthodontics. 2011;17(1):20-33.
[23] Sriphadungporn C, Chamnannidiadha N. Perception of smile esthetics by laypeople of different ages. Prog Orthod. 2017;18(1):8.
[24] Choi JW, Lee JY, Oh TS, Kwon SM, Yang SJ, Koh KS. Frontal soft tissue analysis using a 3 dimensional camera following two-jaw rotational orthognathic surgery in skeletal class III patients. J Craniomaxillofac Surg. 2014;42(3):220-26.
[25] Moshiri S, Araújo EA, McCray JF, Thiesen G, Kim KB. Cephalometric evaluation of adult anterior open bite non-extraction treatment with Invisalign. Dental Press J Orthod. 2017;22(5):30-38.
[26] Faber J. Patient-centered innovation for better care. Journal of the World Federation of Orthodontists. 2015;4(3):107.
[27] Hägg U, Taranger J. Menarche and voice change as indicators of the pubertal growth spurt. Acta Odontol Scand. 1980;38(3):179-86.
[28] Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJWL. Artificial intelligence in radiology. Nat Rev Cancer. 2018;18(8):500-10.
[29] Arık SÖ, Ibragimov B, Xing L. Fully automated quantitative cephalometry using convolutional neural networks. J Med Imaging (Bellingham). 2017;4(1):014501.
[30] Poedjiastoeti W, Suebnukarn S. Application of convolutional neural network in the diagnosis of jaw tumors. Healthc Inform Res. 2018;24(3):236-41.
[31] Laurenziello M, Montaruli G, Gallo C, Tepedino M, Guida L, Perillo L, et al. Determinants of maxillary canine impaction: Retrospective clinical and radiographic study. J Clin Exp Dent. 2017;9(11):e1304-09.
[32] Hesamian MH, Jia W, He X, Kennedy P. Deep learning techniques for medical image segmentation: Achievements and challenges. J Digit Imaging. 2019;32(4):582-96.
[33] Wang L, Gao Y, Shi F, Li G, Chen KC, Tang Z, et al. Automated segmentation of dental CBCT image with prior-guided sequential random forests. Med Phys. 2016;43(1):336.
[34] Ahmed N, Chethana, Aymen U, Rahul NA. Artificial intelligence in orthodontics: A way towards modernization. IP Indian Journal of Orthodontics and Dentofacial Research. 2023;9(1):03-07.
[35] Buschang PH, Roldan SI, Tadlock LP. Guidelines for assessing the growth and development of orthodontic patients. Seminars in Orthodontics. 2017;23(4):321-35.
[36] 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.
[37] 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):262-66.
[38] Choi E, Kim D, Lee JY, Park HK. Artificial intelligence in detecting temporomandibular joint osteoarthritis on orthopantomogram. Sci Rep. 2021;11:10246.
[39] Han S. The Fourth Industrial Revolution and oral and maxillofacial surgery. J Korean Assoc Oral Maxillofac Surg. 2018;44(5):205-06.
[40] Choi HI, Jung SK, Baek SH, Lim WH, Ahn SJ, Yang IH, et al. Artificial intelligent model with neural network machine learning for the diagnosis of orthognathic surgery. J Craniofac Surg. 2019;30(7):1986-89.
[41] Knoops PGM, Papaioannou A, Borghi A, Breakey RWF, Wilson AT, Jeelani O, et al. A machine learning framework for automated diagnosis and computer-assisted planning in plastic and reconstructive surgery. Sci Rep. 2019;9(1):13597.
[42] Weichel F, Eisenmann U, Richter S, Hagen N, Rückschloß T, Freudlsperger C, et al. A computer-assisted optimization approach for orthognathic surgery planning. Current Directions in Biomedical Engineering. 2019;5(1):41-44.
[43] Patcas R, Bernini DAJ, Volokitin A, Agustsson E, Rothe R, Timofte R. 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.
[44] Scerri M, Grech V. Artificial intelligence in medicine. Early Hum Dev. 2020;145:105017.
[45] König IR, Fuchs O, Hansen G, von Mutius E, Kopp MV. What is precision medicine? Eur Respir J. 2017;50(4):1700391.
[46] Jheon AH, Oberoi S, Solem RC, Kapila S. Moving towards precision orthodontics: An evolving paradigm shift in the planning and delivery of customized orthodontic therapy. Orthod Craniofac Res. 2017;20(Suppl 1):106-13.

[47] Hung HC, Wang YC, Wang YC. Applications of artificial intelligence in orthodontics. Taiwanese Journal of Orthodontics. 2020;32(2):3.

[48] Dhopte A, Bagde H. Smart smile: Revolutionizing dentistry with artificial intelligence. Cureus. 2023;15(6):e41227.

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