Journal of Advanced Medical and Dental Sciences Research

@Society of Scientific Research and Studies *NLM ID: 101716117*

Journal home page: www.jamdsr.com doi: 10.21276/jamdsr Indian Citation Index (ICI) Index Copernicus value = 100

(e) ISSN Online: 2321-9599; (p) ISSN Print: 2348-6805

Review Article

Role of artificial intelligence in orthodontics; working smarter not harder

[1]Neeharika Mittal, [2]Nidhi Sharma, [3]Pradeep Raghav, [4]Anupriya Srivastava

[1,2]Intern, Subharti Dental College, SVSU, Meerut, India;
[3]Professor and Head, [4]Assistant Professor, Department of Orthodontics and Dentofacial Orthopedics, Subharti Dental College, SVSU, Meerut, India

ABSTRACT:
This article aims to discuss an outline of artificial intelligence uses in orthodontic for clinical diagnosis. In past few years, technology has guided the route for digitalization in orthodontics that has significantly enhanced as well as streamlined the diagnosis and treatment planning. This article explores the application of AI in orthodontics such as cephalometric analysis, determination of skeletal age, orthognathic surgery planning. However AI has shown great effectiveness for all these purposes, performance variance and need for clinician supervision raise concerns about its use in clinical practice. Successful introduction of AI in field of orthodontic practice requires continuous learning, proper governance and ethical concerns.Artificial intelligence technology has been a game-changer in the healthcare system in recent years, and its use in orthodontics has grown significantly as well. Artificial intelligence (AI) is a fantastic tool for orthodontists because it can be used for diagnosis and treatment planning. Automation can eliminate labour costs and expedite the diagnosis and treatment procedures.As orthodontics becomes more digitally advanced, some orthodontic manufacturing procedures, like wire bending, aligner production, and indirect bonding tray fabrication, can be automated. Planning and evaluating orthodontic treatments, however, is still the responsibility of specialists. Orthodontists use features gathered from longitudinal, multimodal, and standardized orthodontic data sets because it is difficult and unique to predict how orthodontic patients will grow and respond to treatment.Together with improvements in its functionality, we have seen the use of AI in orthodontics expand. This review also describes the field's current limitations and provides insights for the future.
Key words: orthognathic surgery, artificial intelligence, orthodontic treatment.

Received: 27 December, 2024 Accepted: 30 January, 2025

Corresponding author: Neeharika Mittal, Intern, Subharti Dental College, SVSU, Meerut, India

This article may be cited as: Mittal N, Sharma N, Raghav P, Srivastava A. Role of artificial intelligence in orthodontics; working smarter not harder. J Adv Med Dent Scie Res 2025; 13(2):64-69.

INTRODUCTION
The ability of a machine to simulate human thought processes is known as artificial intelligence (AI), a branch of computer science. Since AI may be used to solve a wide range of problems, the field has shown a lot of applications during the past 10 years.[1] Thephrase "artificial intelligence" was introduced by John McCarthy in 1956. The quality of a this technology to simulate a manual based knowledge which is capable of rational behaviour, critical thought, and optimal decision-making is known as artificial intelligence (AI)
The three main areas of artificial intelligence (AI) in diagnostic imaging are operational AI, which enhances the delivery of healthcare; diagnostic AI, which aids in the interpretation of clinical images; and predictive AI, which forecasts future outcomes.[2]Better diagnosis, treatment planning, growth and development estimation, maintenance phase, gap supervision, and long-term follow-up are all made possible by dentists using AI.[3]The detection of cephalometric points and treatment plan are two of the many complex tasks that are part of orthodontic operations and both require accuracy and efficiency. Additionally, accurate treatment planning depends on the identification of malocclusion and the explanation of imaging data. These orthodontic needs could be met with the use of AI technologies, which automate processes, improve accuracy, and reduce variability. Many research have applied the AI automation for human orthodontic diagnostic purposes for example malocclusion diagnosis, noting of landmarks and cephalometric analysis.[4,5]
Although studies have implemented AI for decision making of orthodontic treatment which assist clinically to decide the need for extraction of tooth or

orthognathic surgery for desirableclinical results. However, a thorough analysis and reviewing of previous studies on uses of AI for different orthodontic purposes, considering their effectiveness, dependability and time saving.

AI CATEGORIES

AI can be divided into two primary domains: symbolic AI and machine learning (ML) [6]Symbolic AI includes building an algorithm in such a manner that it is effortlessly acceptable manually.(figure 1)

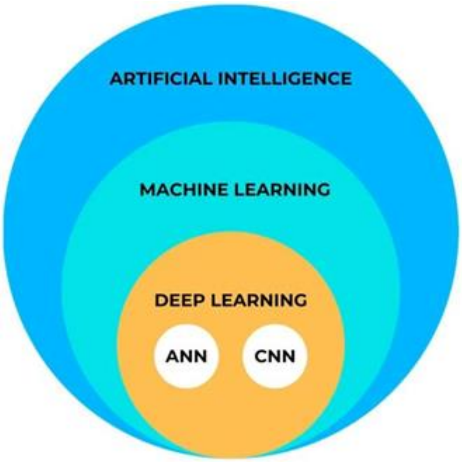

Figure1: Illustrates aschematic representation of AI

MACHINE LEARNING

In AI, machine learning (ML) is the most used model. ML, which was first used by Arthur Samuel in 1952, is distinct from symbolic AI in that it uses models that are learnt from instances as opposed to human-established rules.

DEEP LEARNING

As a part of machine learning (ML), deep learning (DL) entails machines autonomously calculating particular input properties. DL is an extension of artificial neural networks (ANNs), which were created in the 1990s. Researchers may now build more intricate neural networks, or "deeper" networks, to tackle increasingly difficult problems because to recent developments in computational technology. With great diagnostic accuracy, DL techniques primarily use convolutional neural networks (CNNs) in the dental imaging domain.[7,8, 9]

ARTIFICIAL NEURAL NETWORKS(ANN)

The brain's structure served as the foundation for the introduction of artificial neural networks, which are certainly capable of simulating human brains. One of the earliest neural networks in history was the stochastic neural analog reinforcement calculator, developed in 1951 by Minsky and Dean Edmunds. [10]Figure 2)

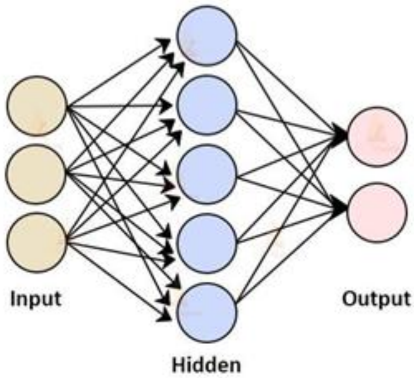

Figure 2 Shows Artificial Neural Networks (ANN)

APPLICATIONS OF AI IN ORTHODONTICS

ORTHODONTIC DIAGNOSIS

The utilization of medical imaging techniques is important for dental patients because it helps in identifying different oral pathologies which is related to soft and hard tissue structure. Radiological techniques, such as orthopantomograms (OPGs) and cone-beam computed tomography (CBCT), has significant roles in orthodontic diagnosis, treatment planning, and patient monitoring. [11]CNNs are used in the AI-based system created by Diagnocat Ltd. (San Francisco, CA, USA) to give accurate and thorough dental diagnostics. Volumetric assessment, clinical diagnosis (such as periapical lesions and caries), and tooth segmentation and enumeration are all made possible by the technology. Numerous academic studies have confirmed this program's diagnostic capabilities, highlighting its great accuracy and efficacy.

The purpose of Ho-Jin Kim et al.'s [12]study was to investigate the classification of sagittal skeletal relationships using an AI model driven by a deep convolutional neural network (DCNN) and cephalometric photos. Additionally, it sought to evaluate how well this recently created DCNN-based AI model performed in comparison to an automated tracing AI program.[13, 14, 15]

CEPHALOMETRIC ANALYSIS

Accurate Cephalometric analysis of patient development and occlusion depends on the ability to recognize anatomic landmarks from a lateral cephalogram. AI makes it possible to evaluate lateral radiographs.Since 1998, research on AI's ability to recognize cephalometric landmarks has been conducted. Numerous research have constantly reached great accuracy in landmark detection using a variety of automated methods.

According to a recent study by Hwang et al.[16], automated cephalometric landmark detection could match the accuracy of a skilled manual reader. Likewise, Kim et al.[17], Lee et al.[18] and Dobratulin et al. [19]used AI to attain historic definition accuracies of 88% to 92%. These scientists also discovered that AI techniques lowered the amount of time and human labour needed and showed higher accuracy in landmark identification when compared to manual methods.

SKELETAL MATURATION DETERMINATION

Finding out a patient's development spurt is essential for orthodontic treatment, particularly for those who require orthopaedic and functional therapy. The most common and reliable method for determining skeletal age has been thought to be hand-wrist X-rays. AI and hand-wrist radiographs have been used in a number of investigations in recent years to predict skeletal age. Numerous researchhas demonstrated that the cervical vertebral maturation (CVM) approach is significantly correlated with the hand-wrist radiograph method and is also useful for estimating ofgrowth.[20 21 22]

CNN-based models have achieved over 90% accuracy in CVM assessments, according to Seo et al. [23], who also explained that skeletal maturity can be accurately identified through automatic diagnosis using lateral cephalograms.Kök et al. identified the stages of CVM using seven distinct machine-learning algorithms. The results demonstrated that while these algorithms had differing degrees of accuracy in identifying the various stages of CVM, the ANN was thought to be the most reliable algorithm for identifying every stage of CVM.

DECISION MAKING FOR EXTRACTION

In past few years, a variety of artificial intelligence (AI) systems were developed to aid with orthodontic treatment decision-making. The AI algorithms reaching over 80% agreement with expert conclusions, early research on extraction decision aids has produced encouraging findings. Although only 20 cases were examined, Xie's (2010)[24] study found that AI and experts agreed on 80% of extraction decisions. An ANN system that Jung and King tested,Based on 12 cephalometric factors, there is an 84% success rate for the full diagnosis of some extractions.[25]

Considering these drawbacks, it is crucial to recognize that it might be difficult to decide whether to move further with orthodontic extraction therapy, particularly in cases that are indecisive. Physicians must carefully weigh the benefits and drawbacks of each therapeutic strategy while taking the entire clinical scenario into account.

ORTHOGNATHIC SURGERY PLANNING

Repositioning the jaws in adult patients with significant dentofacial abnormalities typically requires a combination of orthodontic and orthognathic surgical treatment.

Another important consideration when deciding whether to get surgery or not is facial attractiveness. Using 3D facial scans and SVM, Knoops et al. achieved a 95.4% accuracy rate in predicting a surgery/non-surgery decision. Choi used a variety of factors as training data, with the main issue being protrusion. These factors included dental, profile, and lateral cephalogram variables. [26]In addition to forecasting decision to have surgery or not, the suggested ANN model also predicted the surgical case's tooth extraction plan, that obtain a 88% to 97% range of accuracy. Though it has the potential to increase AI's diagnostic capabilities, additional work is still needed to incorporate a more complete variety of instances, particularly more borderline ones.

AI GUIDED TREATMENT OUTCOME PREDICTION

By predicting treatment outcomes, orthodontists can lessen the risks and complications during and after the treatment by using a more scientific approach to the analysis and treatment of malocclusions. AI can currently help guide treatment planning by anticipating changes in the teeth, skeleton, and face as well as patients' experiences with clear aligners. Woo et al. investigated the accuracy of a manual setup with respect to six tooth movement directions. [27] Although additional manual adjustments might still be necessary in clinical practice, the outcomes demonstrated the overall effectiveness of the automated virtual-setup software components.

ROLE OF AI IN CLEAR ALIGNERS

Dentists have seen the transition from traditional fixed appliances to transparent aligners during the past few decades. [28] Patients' desire for orthodontic treatments that are more visually beautiful, pleasant, and convenient is primarily responsible for this shift. Because clear aligners are detachable, they don't impede brushing or flossing, which promotes oral cleanliness, and they don't limit a patient's food options.[29]With a success rate of 80% to 90%, aligners are a good alternative for treating mild to moderate orthodontic situations, which benefits orthodontics professionals as well.[30] In addition, compared to traditional orthodontic treatments, clear aligners are mild painful and might lessen the frequency and intensity of root resorption. The advancement of clear aligner technology has coincided with advancements in artificial intelligence. [31 32]

CLINICAL PRACTICE

Orthodontists frequently face a number of difficulties when providing orthodontic treatment, such as managing and communicating with patients and requiring clinical orthodontic expertise. AI applications can support more effective and efficient orthodontic treatment in terms of clinical documentation, practice guidance, and remote care.

DISCUSSION

The review that follows offers thorough and current incorporation of AI applications in orthodontic diagnosis and treatment planning by comparing the effectiveness of AI-based model to manual based techniques, without going into comparisons among various AI models or algorithms. Previous evaluations frequently focused on certain tasks or limited their findings to specific AI algorithms [33,34] which resulted in a fragmented view of the field. A more focused approach is taken in this analysis, which thoroughly examines all pertinent areas, even if previous studies have provided insightful information on the wider context of AI applications in orthodontics.[35] [36]This method emphasizes how AI technology directly improves the accuracy and efficiency of orthodontic workflows while also posing special problems and possibilities. A crucial aspect of orthodontics is converting complex orthodontic needs into precisely specified AI tasks, which calls for meticulous attention to detail and methodological clarity. For instance, activities such as cephalometric analysis include converting the work into a computer one, which includes identifying or annotating landmarks on lateral cephalograms. Segmenting teeth is also necessary for forecasting treatment results. Additionally, the best course of therapy is determined using clinical factors as training data. Improvising the working of AI system is mostly dependent on the experts' skills throughout the training process. As a result, the people in charge of producing training datasets ought to be highly skilled in this area. [37]Interestingly, AI can demonstrate more consistency than manual procedures by skilled clinicians, overcoming the constraint of observer variability. Though AI has less chance of variability, forcoming advancements are required to guarantee that landmarks are positioned as accurately as those specified by professional doctors, as evidenced by the fact that its accuracy has not yet regularly outperformed that of human specialists.[38]On lateral cephalometric pictures, landmark detection was employed in the majority of studies. It's crucial to recognize that, because of certain restrictions like distortion, superimposition, and magnification, a 2D projection may result in an incorrect depiction of 3D anatomical features. The necessity to investigate 3D landmark detection has increased due to the growing usage of 3D imagery in orthodontic case management.[39]These developments signal improved patient outcomes and more effective clinical processes, marking a paradigm change in orthodontic care. The automated identification of orthodontic treatment needs, such as the index of orthodontic treatment need (IOTN) and index of orthognathic functional treatment need (IOFTN), is one area where artificial intelligence (AI) could be further explored, despite the fact that it has been thoroughly studied in orthodontic treatment. [40,41] Interestingly, AI can demonstrate more consistency than manual procedures by skilled clinicians, overcoming the constraint of observer variability. Though AI is less prone to fluctuation, more advancements are required to guarantee that landmarks are put as accurately as those selected by human specialists, as its accuracy has not yet regularly outperformed theirs.AI is now quite good at diagnosing orthodontic issues, but it can't provide much advise on how to proceed with therapy. Treating the deep overbites and preventing bone dehiscence or fenestration are only two of the difficulties that orthodontists may face during orthodontic therapy. Another possible area for future research is the use of AI to help avoid or address these problems. Without a doubt, artificial intelligence (AI) will greatly boost the field of orthodontics as clinical data continues to rise and AI processing power increases.

LIMITATIONS OF AI

According to these findings, the use of AI in orthodontics has advanced in a promising manner and holds tremendous promise for future clinical applications. Nevertheless, there are still certain restrictions that might make the planned use of AI in orthodontics impossible.

First off, the current research is less trustworthy because of the limited quantity and poor generalizability of training data. For instance, several AI models employed to support process of definite decision for desired prognosis,did not integrate a wide variety of typical case types in the training data; despite achieving encouraging efficacy, their anticipation for certain uncommon deformity kinds is dubious. These findings are included in this review. Getting a sizable amount of accurate data is still difficult, specifically for data that needs to be manually annotated by knowledgeable professionals. A number of techniques, including transfer learning, augmentation of data, semi-supervised learning, and few-shot learning, are anticipated to lessen the severity of data insufficiency.

Norgeot et al. suggested minimum information about clinical artificial intelligence modelling (MI-CLAIM), which aims to provide clinical AI modelling with similar levels of efficacy. [42] In addition to making it easier to evaluate the clinical impact of AI research, the MI-CLAIM checklist helps researchers quickly duplicate the technical design process.

CAN AI REPLACE HUMANS

AI is primarily electronic in nature rather than biological. A subset of artificial intelligence called machine learning is used to identify statistical data patterns and structures in order to create a model that predicts the results of unseen data. [43]Hence, it necessitates gathering and disseminating vast amounts of data, which may raise several ethical, privacy, and safety problems. Thus, it is still necessary to address and analyse the possible drawbacks and future developments of AI in clinical dentistry.

In terms of clinical practice, modern dentistry emphasizes clinical knowledge and clinical skills, medical history taking, general examination, communication between patients and dentists, and mmedical humanities. [44] There would be less in-person interaction with patients and their families if AI were used in clinical dentistry.

CONCLUSION

Orthodontists are always looking for ways to make diagnostic and treatment planning processes more accurate, dependable, and time efficient. When compared to expert manual skills, AI has proven to be an effective tool for lowering operator variability, human mistake, and consumption of time. This review has demonstrated that a number of trials assess the efficacy of AI in the diagnosis stage and in selecting the best course of treatment for the patient, yielding outcomes that are on par with those that are manually determined by specialists. It offers accurate and automatic tracking of the course of orthodontic therapy. Additionally, the use of AI in clear aligner therapy remote monitoring and evaluation shows how technology can improve patient compliance and treatment effectiveness.

REFERENCES

1. Kulikowski C.A. An Opening Chapter of the First Generation of Artificial Intelligence in Medicine: The First Rutgers AIM Workshop, June 1975. Yearb. Med. Inform. 2015;10:227–233.
2. Pianykh, O.S.; Langs, G.; Dewey, M.; Enzmann, D.R.; Herold, C.J.; Schoenberg, S.O.; Brink, J.A. Continuous Learning AI in Radiology: Implementation Principles and Early Applications. *Radiology* **2020**, *297*; 6–14.
3. Subramanian, A.K.; Chen, Y.; Almalki, A.; Sivamurthy, G.; Kafle, D. Cephalometric Analysis in Orthodontics Using Artificial Intelligence-A Comprehensive Review. BioMed Res. Int. **2022**, 2022; 1880113.
4. S.O. ¨ Arik, B. Ibragimov, L. Xing, Fully automated quantitative cephalometry using convolutional neural networks, J. Med. Imaging 4 (1) (2017) 014501.
5. S. Talaat, A. Kaboudan, W. Talaat, B. Kusnoto, F. Sanchez, M.H. Elnagar, C. Bourauel, A. Ghoneima, The validity of an artificial intelligence application for assessment of orthodontic treatment need from clinical images, Semin. Orthod. 27 (2) (2021) 164–171
6. Williams, M.; Haugeland, J. Artificial Intelligence: The Very Idea. Technol. Cult. 1987; 28, 706.
7. Rajpurkar, P.; Irvin, J.; Ball, R.L.; Zhu, K.; Yang, B.; Mehta, H.; Duan, T.; Ding, D.; Bagul, A.; Langlotz, C.P.; et al. Deep Learning for Chest Radiograph Diagnosis: A Retrospective Comparison of the CheXNeXt Algorithm to Practicing Radiologists. *PLoS Med.* **2018**; *15*, e1002686
8. Chilamkurthy, S.; Ghosh, R.; Tanamala, S.; Biviji, M.; Campeau, N.G.; Venugopal, V.K.; Mahajan, V.; Rao, P.; Warier, P. Deep Learning Algorithms for Detection of Critical Findings in Head CT Scans: A Retrospective Study. *Lancet* **2018**; *392*, 2388–22396.
9. Yu, A.C.; Mohajer, B.; Eng, J. External Validation of Deep Learning Algorithms for Radiologic Diagnosis: A Systematic Review. Radiol. Artif. Intell. 2022, 4, e210064.
10. Srivastava A, Pradhan S, Raghav P, Artificial intelligence in Dentistry: the ethical and regulatory issues, Neuroquantology, 2022; 20(11) : 6955
11. Hajem, S.; Brogårdh-Roth, S.; Nilsson, M.; Hellén-Halme, K. CBCT of Swedish Children and Adolescents at an Oral and Maxillofacial Radiology Department. A Survey of Requests and Indications. Acta Odontol. Scand. 2020; 78, 38–44.
12. Kim, H.-J.; Kim, K.D.; Kim, D.-H. Deep Convolutional Neural Network-Based Skeletal Classification of Cephalometric Image Compared with Automated-Tracing Software. Sci. Rep. 2022; 12, 11659.
13. Issa, J.; Jaber, M.; Rifai, I.; Mozdziak, P.; Kempisty, B.; Dyszkiewicz-Konwińska, M. Diagnostic Test Accuracy of Artificial Intelligence in Detecting Periapical Periodontitis on Two-Dimensional Radiographs: A Retrospective Study and Literature Review. Medicina 2023, 59, 768.
14. Orhan, K.; Shamshiev, M.; Ezhov, M.; Plaksin, A.; Kurbanova, A.; Ünsal, G.; Gusarev, M.; Golitsyna, M.; Aksoy, S.; Mısırlı, M.; et al. AI-Based Automatic Segmentation of Craniomaxillofacial Anatomy from CBCT Scans for Automatic Detection of Pharyngeal Airway Evaluations in OSA Patients. Sci. Rep. 2022, 12, 11863.
15. Vujanovic, T.; Jagtap, R. Evaluation of Artificial Intelligence for Automatic Tooth and PeriapicalPathosis Detection on Panoramic Radiography. Oral. Surg. Oral. Med. Oral. Pathol. Oral. Radiol. 2023, 135.
16. Hwang, H.W.; Park, J.H.; Moon, J.H.; Yu, Y.; Kim, H.; Her, S.B.; Srinivasan, G.; Aljanabi, M.N.A.; Donatelli, R.E.; Lee, S.J. Automated Identification of Cephalometric Landmarks: Part 2-Might It Be Better than Human? *Angle Orthod.* **2020**; *90*, 69–76
17. Kim, H.; Shim, E.; Park, J.; Kim, Y.J.; Lee, U.; Kim, Y. Web-Based Fully Automated Cephalometric Analysis by Deep Learning. *Comput. Methods Programs Biomed.* **2020**; *194*, 105513.
18. Lee, J.H.; Yu, H.J.; Kim, M.J.; Kim, J.W.; Choi, J. Automated Cephalometric Landmark Detection with Confidence Regions Using Bayesian Convolutional Neural Networks. *BMC Oral Health* **2020**; *20*, 270.
19. Dobratulin, K.; Gaidel, A.; Kapishnikov, A.; Ivleva, A.; Aupova, I.; Zelter, P. The Efficiency of Deep Learning Algorithms for Detecting Anatomical Reference Points on Radiological Images of the Head Profile. In Proceedings of the ITNT 2020–6th IEEE International Conference on Information Technology and Nanotechnology, Samara, Russia, 26–29 May 2020.
20. Baccetti, T.; Franchi, L.; McNamara, J.A. The Cervical Vertebral Maturation (CVM) Method for the Assessment of Optimal Treatment Timing in Dentofacial Orthopedics. Semin. Orthod. 2005, 11, 119–129.
21. Uysal, T.; Sari, Z.; Ramoglu, S.I.; Basciftci, F.A. Relationships between Dental and Skeletal Maturity in Turkish Subjects. Angle Orthod. 2004, 74, 657–664.
22. Jourieh, A.; Khan, H.; Mheissen, S.; Assali, M.; Alam, M.K. The Correlation between Dental Stages and Skeletal Maturity Stages. Biomed. Res. Int. 2021, 2021, 9986498.
23. Seo, H.; Hwang, J.; Jeong, T.; Shin, J. Comparison of Deep Learning Models for Cervical Vertebral Maturation Stage Classification on Lateral Cephalometric Radiographs. *J. Clin. Med.* **2021**; *10*, 3591.
24. Xie, X.; Wang, L.; Wang, A. Artificial Neural Network Modeling for Deciding If Extractions Are Necessary Prior to Orthodontic Treatment. *Angle Orthod.* **2010**; *80*, 262–266
25. Jung, S.K.; Kim, T.W. New Approach for the Diagnosis of Extractions with Neural Network

Machine Learning. Am. J. Orthod. Dentofac. Orthop. 2016, 149, 127–133.
26. Choi H.-I., Jung S.-K., Baek S.-H., Lim W.H., Ahn S.-J., Yang I.-H., Kim T.-W. Artificial intelligent model with neural network machine learning for the diagnosis of orthognathic surgery. J. Craniofacial Surg. 2019;30:1986–1989.
27. Woo H., Jha N., Kim Y.-J., Sung S.-J. Evaluating the accuracy of automated orthodontic digital setup models. Semin. Orthod. 2023;29:60–67
28. AlMogbel Clear Aligner Therapy: up to date review article J. Orthod. Sci., 12 (2023), p. 37, 10.4103/jos.jos_30_23
29. Zhang, X. Huang, S. Huo, C. Zhang, S. Zhao, X. Cen, et al. Effect of clear aligners on oral health-related quality of life: a systematic review Orthod. Craniofac. Res., 23 (2020), pp. 363-370, 10.1111/ocr.1238
30. M. Bouchant, A. Saade, M. El HelouIs maxillary arch expansion with Invisalign® efficient and predictable? A systematic review Int. Orthod., 21 (2023), Article 100750, 10.1016/j.ortho.2023.100750
31. Thurzo, V. Kurilová, I. Varga Artificial intelligence in orthodontic smart application for treatment coaching and its impact on clinical performance of patients monitored with AI-telehealth system Healthcare (Basel), 9 (2021); p. 1695, 10.3390/healthcare9121695
32. S.B. Khanagar, A. Al-Ehaideb, P.C. Maganur, S. Vishwanathaiah, S. Patil, H.A. Baeshen, et al. Developments, application, and performance of artificial intelligence in dentistry - a systematic review J. Dent. Sci., 16 (2021), pp. 508-522, 10.1016/j.jds.2020.06.019
33. J. Hendrickx, R.S. Gracea, M. Vanheers, N. Winderickx, F. Preda, S. Shujaat, R. JacobsCan artificial intelligence-driven cephalometric analysis replace manual tracing? A systematic review and meta-analysis Eur. J. Orthod., 46; (4) (2024)
34. Surendran, P. Daigavane, S. Shrivastav, R. Kamble, A.D. Sanchla, L. Bharti, M. ShindeThe future of orthodontics: deep learning technologies Cureus, 16; (6) (2024)
35. Y.M. Bichu, I. Hansa, A.Y. Bichu, P. Premjani, C. Flores-Mir, N.R. Vaid Applications of artificial intelligence and machine learning in orthodontics: a scoping review Prog. Orthod., 22; (1) (2021)
36. S.B. Khanagar, A. Al-Ehaideb, S. Vishwanathaiah, P.C. Maganur, S. Patil, S. Naik, H.A. Baeshen, S.S. Sarode Scope and performance of artificial intelligence technology in orthodontic diagnosis, treatment planning, and clinical decision-making – A systematic review J. Dent. Sci., 16; (1) (2021), pp. 482-492
37. J. Prasad, D.R. Mallikarjunaiah, A. Shetty, N. Gandedkar, A.B. Chikkamuniswamy, P.C. Shivashankar Machine learning predictive model as clinical decision support system in orthodontic treatment planning Dent. J., 11; (1) (2022)
38. H.J. Yu, S.R. Cho, M.J. Kim, W.H. Kim, J.W. Kim, J. Choi Automated skeletal classification with lateral cephalometry based on artificial intelligence J. Dent. Res., 99; (3) (2020), pp. 249-256
39. G. Dot, T. Schouman, S. Chang, F. Rafflenbeul, A. Kerbrat, P. Rouch, L. GajnyAutomatic 3-dimensional cephalometriclandmarking via deep learning J. Dent. Res., 101; (11) (2022), pp. 1380-1387
40. Borzabadi-Farahani A. An insight into four orthodontic treatment need indices. Prog. Orthod. 2011;12:132–142.
41. Borzabadi-Farahani A., Eslamipour F., Shahmoradi M. Functional needs of subjects with dentofacial deformities: A study using the index of orthognathic functional treatment need (IOFTN) J. Plast. Reconstr. Aesthet. Surg. 2016;69:796–801.
42. Norgeot B., Quer G., Beaulieu-Jones B.K., Torkamani A., Dias R., Gianfrancesco M., Arnaout R., Kohane I.S., Saria S., Topol E., et al. Minimum information about clinical artificial intelligence modeling: The MI-CLAIM checklist. Nat. Med. 2020;26:1320–1324. doi: 10.1038/s41591-020-1041.
43. Hornik K. Approximation capabilities of multilayer feedforward networks. Neural Network. 1991;4:251–257.
44. Huang Y.K., Chen Y.T., Chang Y.C. Initiating narrative medicine into dental education: opportunity, change, and challenge. J Formos Med Assoc. 2021;120:2191–2194.
45. Singh HP, Kumar P, Goel R, Kumar A. Sex hormones in head and neck cancer: Current knowledge and perspectives. Clin Cancer Investig J. 2012;1(1):2-5. https://doi.org/10.4103/2278-0513.95011