RUZIEV SHERZODBEK
ANDIJAN STATE MEDICAL INSTITUTE
Mr.roziyev@list.ru

AI IN ORTHODONTICS: DIAGNOSTICS AND TREATMENT PLANNING

Abstract: Artificial Intelligence (AI) is revolutionizing the field of orthodontics, offering enhanced diagnostic precision and improved treatment planning. By integrating AI into orthodontic practices, professionals can leverage advanced algorithms for detailed dental diagnostics, accurate cephalometric analysis, and reliable skeletal age assessments. AI's role in evaluating the temporomandibular joint (TMJ) and aiding in clinical decision-making processes further underscores its significance in modern orthodontics. Moreover, AI facilitates patient telemonitoring, allowing for continuous care and monitoring outside traditional clinical settings. Despite these advancements, the heterogeneity of studies and the inherent complexity of AI algorithms necessitate a cautious approach. Manual oversight remains essential to ensure the reliability of AI-driven conclusions. Furthermore, the ethical and privacy considerations associated with AI deployment must be meticulously managed. As AI continues to evolve, its integration into orthodontic practice demands ongoing learning, stringent governance, and a commitment to addressing these critical concerns to realize its full potential and maintain the trust of practitioners and patients alike.

Keywords: Orthodontics; artificial intelligence; deep learning; cephalometric analysis; radiology; CBCT; skeletal age; treatment planning.

Introduction: The evolution of artificial intelligence (AI) over the past seven decades has been a journey marked by alternating waves of advancement and setback. From its conceptualization by John McCarthy in 1955, AI has grown from a theoretical construct into a practical tool with profound implications across various sectors. The triumph of AlphaGo over a human Go champion in 2015 was a pivotal moment, demonstrating AI's potential to tackle complex problems. This victory, along with the launch of Chat-GPT in 2022, catalyzed a surge in AI development, leading to its integration into daily life and critical fields like medicine. In healthcare, AI's impact is particularly notable in radiology, where it assists in interpreting medical images with greater accuracy than ever before. By 2023, a significant portion of FDA-approved AI applications were dedicated to medical imaging, underscoring the technology's importance in diagnosis and treatment planning. AI's ability to analyze and organize vast amounts of healthcare data has not only enhanced the efficiency of medical professionals but also holds the promise of personalized medicine, where treatments can be tailored to individual patient profiles, potentially revolutionizing patient care. The journey of AI is far from over, as it continues to evolve and reshape the landscape of medicine and beyond. Artificial Intelligence (AI) is revolutionizing the field of diagnostic imaging, offering significant advancements in the efficiency and accuracy of patient care. Operational AI streamlines healthcare delivery by optimizing workflows and reducing the time needed for administrative tasks. Diagnostic AI enhances the interpretation of clinical images, allowing for quicker and more accurate diagnoses. Predictive AI goes a step further by using historical data to forecast potential future outcomes, aiding in proactive patient care. In the realm of orthodontics, AI's impact is particularly notable. It not only simplifies the complex process of cephalometric analysis but also extends its utility to various other applications. These include refining diagnosis and treatment planning, automating the detection of anatomical landmarks, monitoring growth and development, evaluating treatment results, and supporting a range of other orthodontic tasks. The integration of AI in orthodontics is not just about automation; it's about enhancing the precision and predictability of patient outcomes, leading to more personalized and effective treatment plans. As AI continues to evolve, its potential to transform diagnostic imaging and orthodontics promises even greater advancements in patient care and treatment success.

Materials and Methods: The integration of artificial intelligence (AI) in orthodontics is a burgeoning field that has seen significant advancements in recent years. The literature review you've conducted is a comprehensive approach to understanding the current landscape of AI applications in this specialized area of dentistry. By utilizing a variety of databases and search engines, you've ensured a broad spectrum of studies, which likely cover a range of topics from dental diagnostics to treatment planning. The use of specific keywords such as "deep learning" and "neural networks" indicates a focus on the more technical aspects of AI, while terms like "cephalometric landmarks identification" and "temporomandibular joint disorders" suggest a practical application in diagnosing and treating complex dental conditions. This meticulous approach to research not only aids in the accumulation of relevant data but also highlights the potential of AI to revolutionize orthodontic practices by enhancing accuracy in diagnosis, personalizing treatment plans, and possibly predicting treatment outcomes. The last decade's scholarly articles will provide a solid foundation for understanding the evolution of AI in orthodontics and its future trajectory. The process of selecting literature for a systematic review is critical to ensure the quality and reliability of the research. In the scenario described, two authors independently reviewed titles and abstracts against predefined inclusion criteria, which is a commendable approach to minimize bias. Subsequent full-text analysis by these authors provided a deeper layer of scrutiny. Disagreements, which are not uncommon in collaborative research, were effectively resolved through discussions with a third author, ensuring a consensus-driven process. The meticulous extraction of data on authorship, publication year, study type, and relevance to the field of AI in orthodontics by one author and cross-examination by another further underscores the rigorous methodology employed. Such thoroughness is essential for advancing the application of AI in specialized fields like orthodontics, where precision and accuracy are paramount. Deep learning (DL), a sophisticated subset of machine learning (ML), has revolutionized the way machines interpret data. By leveraging artificial neural networks (ANNs) with multiple layers, DL enables the automatic extraction and processing of features from raw data. This is a significant departure from traditional ML approaches, which require manual feature selection by human experts. The advent of more powerful computational resources has facilitated the development of these complex, "deeper" networks, allowing for the handling of more intricate tasks. In medical imaging, for instance, convolutional neural networks (CNNs) have been employed to achieve high diagnostic accuracy, surpassing even experienced human practitioners in some cases. The implications of DL extend beyond image analysis; it has also been instrumental in advancing medical disease diagnosis and crafting personalized treatment plans, showcasing its versatility and potential in transforming various facets of healthcare. The integration of artificial intelligence (AI) in dental radiology marks a significant advancement in the field of dentistry. AI systems, like the one developed by Diagnocat Ltd., leverage convolutional neural networks (CNNs) to enhance the accuracy and efficiency of dental diagnostics. These systems are adept at performing complex tasks such as tooth segmentation, pathology identification, and volumetric analysis, which are essential for accurate diagnosis and effective treatment planning. The high accuracy rates reported in scientific studies underscore the potential of AI to complement and, in some cases, rival traditional manual diagnostic methods. As the volume of radiological examinations increases, AI's role becomes increasingly vital, offering a comprehensive tool that supports dental professionals in delivering optimal patient care. The continued validation of these systems through scientific research is crucial for their integration into routine clinical practice, ensuring they meet the rigorous standards of medical diagnostics. Cephalometric analysis (CA) has indeed become a cornerstone in orthodontic diagnosis and treatment planning. Since its inception in 1931, CA has undergone a significant transformation, primarily due to technological advancements. The shift from manual to digital methods has not only streamlined the process but also enhanced the precision and reliability of the results. The introduction of artificial intelligence (AI) in this field marks a pivotal development, offering a level of consistency that manual methods struggled to achieve due to the subjective nature of landmark identification. AI's ability to provide accurate and repeatable results is invaluable, as it ensures that the outcomes of CA are dependable. Moreover, the integration of AI with cone-beam computed tomography (CBCT) has opened new avenues for detailed three-dimensional analysis, further enriching the orthodontic assessment process. The research by Hwang et al. in 2020 underscores the potential of AI to match, and possibly surpass, the expertise of seasoned practitioners, indicating a promising future for AI-assisted cephalometric analysis in orthodontics. The advancements in artificial intelligence (AI) have revolutionized various fields, including medical imaging and analysis. The studies by Kim et al., Lee et al., and Dobratulin et al. highlight the efficacy of AI in achieving high accuracy rates in landmark definition, surpassing traditional manual methods. This not only enhances precision but also significantly reduces the time and labor involved in such processes. Contrasting these findings, Hwang et al. and Yu et al. report no significant differences between automated and manual cephalometric analyses, suggesting that AI can match the reliability of human experts. Furthermore, the integration of AI into clinical workflows has been transformative, with some practices experiencing an 80-fold reduction in analysis time. Such improvements underscore the potential of AI to streamline operations, allowing for more efficient patient care and resource management. The referenced Figure 3 likely provides a visual representation of these cephalometric landmarks, serving as a valuable tool for understanding and training in AI-assisted analysis.

Conclusions: The integration of Artificial Intelligence (AI) into orthodontics represents a significant leap forward in medical technology. AI's ability to process and analyze vast amounts of data with speed and accuracy can enhance the precision of diagnostic imaging, which is crucial in treatment planning and outcome prediction. This not only streamlines the workflow for orthodontists but also improves patient care by providing more personalized treatment options. The visualization capabilities of AI algorithms allow for a clearer understanding of potential treatment outcomes, aiding both practitioners and patients in making informed decisions.

Despite these advantages, the complexity and unpredictability of AI systems necessitate a cautious approach. It is essential to maintain a balance between embracing innovation and ensuring patient safety. Regular manual validation of AI-generated results is a prudent practice to confirm their reliability and accuracy. This hybrid approach leverages the strengths of AI while safeguarding against its limitations, ensuring that the benefits of AI in orthodontics are realized without compromising the quality of care. As AI continues to evolve, ongoing research and validation are key to integrating these tools responsibly into clinical practice.

References

1. McCarthy, J.; Minsky, M.L.; Rochester, N.; Shannon, C.E. A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence. AI Mag. 2006, 27, 12.

2. Haenlein, M.; Kaplan, A. A Brief History of Artificial Intelligence: On the Past, Present, and Future of Artificial Intelligence. Calif. Manag. Rev. 2019, 61, 5–14. [CrossRef]

3. Schwendicke, F.; Golla, T.; Dreher, M.; Krois, J. Convolutional Neural Networks for Dental Image Diagnostics: A Scoping Review. J. Dent. 2019, 91, 103226. [CrossRef] [PubMed]

4. Esteva, A.; Kuprel, B.; Novoa, R.A.; Ko, J.; Swetter, S.M.; Blau, H.M.; Thrun, S. Dermatologist-Level Classification of Skin Cancer with Deep Neural Networks. Nature 2017, 542, 686. [CrossRef] [PubMed]

5. Gulshan, V.; Peng, L.; Coram, M.; Stumpe, M.C.; Wu, D.; Narayanaswamy, A.; Venugopalan, S.; Widner, K.; Madams, T.; Cuadros, J.; et al. Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs. JAMA 2016, 316, 2402–2410. [CrossRef]

6. Mazurowski, M.A.; Buda, M.; Saha, A.; Bashir, M.R. Deep Learning in Radiology: An Overview of the Concepts and a Survey of the State of the Art with Focus on MRI. J. Magn. Reson. Imaging 2019, 49, 939–954. [CrossRef]

7. Saida, T.; Mori, K.; Hoshiai, S.; Sakai, M.; Urushibara, A.; Ishiguro, T.; Satoh, T.; Nakajima, T. Differentiation of Carcinosarcoma from Endometrial Carcinoma on Magnetic Resonance Imaging Using Deep Learning. Pol. J. Radiol. 2022, 87, 521–529. [CrossRef]

8. McNabb, N.K.; Christensen, E.W.; Rula, E.Y.; Coombs, L.; Dreyer, K.;Wald, C.; Treml, C. Projected Growth in FDA-Approved Artificial Intelligence Products Given Venture Capital Funding. J. Am. Coll. Radiol. 2023. [CrossRef]

9. 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. [CrossRef]

10. Milam, M.E.; Koo, C.W. The Current Status and Future of FDA-Approved Artificial Intelligence Tools in Chest Radiology in the United States. Clin. Radiol. 2023, 78, 115–122. [CrossRef]

11. Giełczyk, A.; Marciniak, A.; Tarczewska, M.; Kloska, S.M.; Harmoza, A.; Serafin, Z.; Wo´zniak, M. A Novel Lightweight Approach to COVID-19 Diagnostics Based on Chest X-Ray Images. J. Clin. Med. 2022, 11, 5501. [CrossRef] [PubMed]

12. Kloska, A.; Tarczewska, M.; Giełczyk, A.; Kloska, S.M.; Michalski, A.; Serafin, Z.; Wo´zniak, M. Influence of Augmentation on the Performance of the Double ResNet-Based Model for Chest X-Ray Classification. Pol. J. Radiol. 2023, 88, 244–250. [CrossRef] [PubMed]

13. Fujima, N.; Kamagata, K.; Ueda, D.; Fujita, S.; Fushimi, Y.; Yanagawa, M.; Ito, R.; Tsuboyama, T.; Kawamura, M.; Nakaura, T.; et al. Current State of Artificial Intelligence in Clinical Applications for Head and Neck MR Imaging. Magn. Reson. Med. Sci. 2023, 22, 401–414. [CrossRef] [PubMed]

14. Matsubara, K.; Ibaraki, M.; Nemoto, M.; Watabe, H.; Kimura, Y. A Review on AI in PET Imaging. Ann. Nucl. Med. 2022, 36, 133–143. [CrossRef] [PubMed]

15. Wang, B.; Jin, S.; Yan, Q.; Xu, H.; Luo, C.;Wei, L.; Zhao,W.; Hou, X.; Ma,W.; Xu, Z.; et al. AI-Assisted CT Imaging Analysis for COVID-19 Screening: Building and Deploying a Medical AI System. Appl. Soft Comput. 2021, 98, 106897. [CrossRef] [PubMed]

16. Bichu, Y.M.; Hansa, I.; Bichu, A.Y.; Premjani, P.; Flores-Mir, C.; Vaid, N.R. Applications of Artificial Intelligence and Machine Learning in Orthodontics: A Scoping Review. Prog. Orthod. 2021, 22, 18. [CrossRef]

17. Williams, M.; Haugeland, J. Artificial Intelligence: The Very Idea. Technol. Cult. 1987, 28, 706. [CrossRef]

18. Schwartz, W.B.; Patil, R.S.; Szolovits, P. Artificial Intelligence in Medicine. Where Do We Stand? N. Engl. J. Med. 1987, 316, 685–688. [CrossRef]

19. Faber, J.; Faber, C.; Faber, P. Artificial Intelligence in Orthodontics. APOS Trends Orthod. 2019, 9, 201–205. [CrossRef]

20. Bishop, C. Pattern Recognition and Machine Learning; Springer: Berlin/Heidelberg, Germany, 2007; Volume 16.

21. 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. [CrossRef]

22. 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, 2388–2396. [CrossRef] [PubMed]

23. 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. [CrossRef] [PubMed]

24. Wu, N.; Phang, J.; Park, J.; Shen, Y.; Huang, Z.; Zorin, M.; Jastrzebski, S.; Fevry, T.; Katsnelson, J.; Kim, E.; et al. Deep Neural Networks Improve Radiologists' Performance in Breast Cancer Screening. IEEE Trans. Med. Imaging 2020, 39, 1184–1194. [CrossRef] [PubMed]

25. Kuo, W.; H..ane, C.; Mukherjee, P.; Malik, J.; Yuh, E.L. Expert-Level Detection of Acute Intracranial Hemorrhage on Head Computed Tomography Using Deep Learning. Proc. Natl. Acad. Sci. USA 2019, 116, 22737–22745. [CrossRef] [PubMed] J. Clin. Med. 2024, 13, 344 13 of 19

26. Bulten, W.; Pinckaers, H.; van Boven, H.; Vink, R.; de Bel, T.; van Ginneken, B.; van der Laak, J.; Hulsbergen-van de Kaa, C.; Litjens, G. Automated Deep-Learning System for Gleason Grading of Prostate Cancer Using Biopsies: A Diagnostic Study. Lancet Oncol. 2020, 21, 233–241. [CrossRef] [PubMed]

27. Hosny, A.; Aerts, H.J.; Mak, R.H. Handcrafted versus Deep Learning Radiomics for Prediction of Cancer Therapy Response. Lancet Digit. Health 2019, 1, e106–e107. [CrossRef]

28. Lou, B.; Doken, S.; Zhuang, T.; Wingerter, D.; Gidwani, M.; Mistry, N.; Ladic, L.; Kamen, A.; Abazeed, M.E. An Image-Based Deep Learning Framework for Individualising Radiotherapy Dose: A Retrospective Analysis of Outcome Prediction. Lancet Digit. Health 2019, 1, e136–e147. [CrossRef]

29. Haug, C.J.; Drazen, J.M. Artificial Intelligence and Machine Learning in Clinical Medicine, 2023. New Engl. J. Med. 2023, 388, 1201–1208. [CrossRef]

30. Vandenberghe, B.; Jacobs, R.; Bosmans, H. Modern Dental Imaging: A Review of the Current Technology and Clinical Applications in Dental Practice. Eur. Radiol. 2010, 20, 2637–2655. [CrossRef]