ANALYSIS OF THE POSSIBILITIES OF APPLYING DIGITAL TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE: FROM DIAGNOSTICS TO DISTANCE MONITORING IN ORTHODONTY

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Abstract. *Digitalization stimulates the introduction of innovative technologies such as artificial intelligence (AI), which has a significant impact on all spheres of society. This study focuses on the integration of artificial intelligence in the diagnosis and treatment of orthodontic disorders, taking into account social, economic, and technological aspects.*

The objective *of this review to analyse the capabilities, advantages, limitations, and prospects of artificial intelligence (2018-2025). The methodology includes a review of 25 publications, bibliometric analysis, and assessment of clinical experience.*

The results *demonstrate high accuracy in cephalometry (90-95%), CBCT segmentation (0.93-0.96), planning (0.25 mm/1.2°), and monitoring (30-40% reduction in visits). AI increases treatment effectiveness by 25-40% and reduces complications by 15-20%.*

Conclusion: *AI complements clinical expertise with prospects for data and simulator integration.*

Introduction.

Modern society is experiencing a period of intensive digital transformation driven by the development of artificial intelligence, robotics and computing technologies, bioengineering, and nanotechnologies. These innovations are changing the structure of clinical decision-making, information systematization, and organization of treatment and diagnostic processes, impacting socio-economic aspects, including the labor sphere and educational systems. It also optimizes financial processes and influences ethical and identity approaches. Digitalization is becoming an integral component of standardization and improving the quality of medical care in dentistry, especially in orthodontics [11,2].

Orthodontics is characterized by a high dependence on the accuracy of morphometric measurements, interpretation of visual data, prediction of maxillofacial growth, and assessment of biomechanical characteristics. Traditional diagnostic methods - clinical examination, model analysis, photographic protocols, and cephalometry - are highly subjective and depend on the specialist's experience. [13,4] Inter-expert variability can reach 20-25%, especially when determining bony landmarks in the analysis of severe asymmetries and prognostic assessment of growth.In light of the mounting volume of digital information and the necessity for a customised approach, the deployment of artificial intelligence is emerging as a pivotal instrument for enhancing the efficacy and quality of orthodontic treatment. The automation of analysis of medical imagery, the prediction of treatment outcomes, and remote patient monitoring have been proven to enhance the reproducibility and effectiveness of specialists' work, thereby minimising subjective errors. Furthermore, these technologies positively influence patient experience by improving accessibility and personalisation of medical care.

The objective of review is to analyse the current possibilities of using AI programs and their integration for diagnosis and treatment in orthodontics, in order to identify advantages, limitations, and prospects based on a literature review.The integration of artificial intelligence into dental practice. It has been previously observed that the advent of digital technologies acted as the catalyst for the introduction of artificial intelligence within the domain of orthodontics. During the late 2000s and early 2010s, software programs were initially developed and modified to construct digital jaw models and perform virtual cephalometry, facilitating data storage and analysis. However, manual measurement techniques were still employed.In the mid-2010s, systems based on convolutional neural networks (CNN) emerged that automatically determined cephalometric landmarks, thereby reducing error by 20-30% and shortening analysis time from hours to minutes.

By the end of the 2010s and the advent of the 2020s, artificial intelligence (AI) systems were being trained on thousands of clinical cases, incorporating machine learning to analyse 2D/3D images, predict tooth movements, and assess risks. Consequently, integrated platforms have emerged that are capable of not only diagnosing but also proposing treatment plans.

By 2025, AI programs will have been modified and implemented in clinical processes, including automated segmentation of CBCT (cone-beam computed tomography), digital planning and remote monitoring through mobile applications. These programs have been demonstrated to enhance diagnostic accuracy by 94-97%, curtail visits by 30-40%, and furnish a personalised approach while ensuring the maintenance of ethical control and the consideration of algorithm bias.

Material and methods of research.

Following a comprehensive review of twenty-five articles from both national and international publications on AI, fifteen articles were selected for detailed analysis. The main databases used for literature search were PubMed, ScienceDirect, ResearchGate and PMC. The primary directions for integrating AI into orthodontic practice were identified as follows: automatic diagnosis and image analysis; digital treatment planning and prediction; remote patient monitoring. Furthermore, analytical reports from InsightAce and Precedence Research were considered, as well as open sources containing software descriptions (e.g., technical guides from 3Shape, Align Technology, and Diagnocat).

The review encompassed publications that satisfied the following criteria: The presence of empirical data or clinical observations is an essential component of the study. In addition, the indication of accuracy metrics, effectiveness, or clinical results of AI application is crucial. Finally, the relevance to the dental or orthodontic field is a vital element that must be considered. From the analysis, works containing advertising or theoretical-philosophical materials lacking clinical confirmation, as well as those devoid of quantitative data, were excluded.

The study material highlighted that neural networks were trained on large arrays of medical images using machine learning and deep learning approaches. Machine learning has been employed to analyse 2D/3D images, recognise structures, and measure bite parameters [13]**.** The deep learning (CNN) model has been shown to achieve a level of accuracy in the detection of landmarks on X-rays and CBCT scans that is comparable to that of experts [3]. Each direction exhibited a divergent degree of maturity and clinical integration; however, all were observed to augment the accuracy, velocity and predictability of orthodontic intervention. The evaluation of each publication was conducted using a range of parameters, including but not limited to research design, sample size, applied AI architecture (convolutional, graph, recurrent networks), accuracy, reproducibility, and clinical relevance. In summary, the results obtained were subjected to a comparative analysis, the objective of which was to highlight common trends, advantages, limitations, and development prospects.

The automatic identification of anatomical landmarks on teleradiographs represents the initial and most well-established domains of artificial intelligence integration within the field of dentistry.

CNN-based models have been employed to measure angles and distances between key points of the skull, jaws, and teeth with the objective of diagnosing skeletal anomalies and planning treatment [13]**.** These models have been shown to identify up to 80-100 points with an accuracy of up to 2 mm and a detection rate >90% [4,5]**.** Programmes such as CephX, Diagnocat AI and OrthoVision were able to analyse images within a time frame of 5-10 seconds, producing reports that included measurements (SNA, SNB, ANB) and interpretations [4]**.** This reduction in inter-expert variability was found to be between 20-30%, with a corresponding decrease in diagnostic time of up to 80%. The following limitations should be noted:

- Image quality and paediatric characteristics (error up to 3-4 mm).
- Asymmetries, injuries or metal structures require manual verification or image preparation.

In the field of three-dimensional visualisation, the application of artificial intelligence has led to significant advancements, particularly in the context of automatic segmentation of anatomical structures such as teeth, bones, nasal sinuses, and nerve canals, as evidenced by the literature [7]. Programmes such as Diagnocat 3D and 3Shape have been developed to facilitate surgical planning and risk analysis, with the objective of reducing complications arising from mini-implants. Accurate determination of inter-root space (as indicated by a similarity coefficient of 0.93-0.96) has been shown to reduce complications by up to 30%. The following limitations should be noted:

- Artefacts resulting from braces or implants have been observed to decrease accuracy by 10-15%.
- The dependence on the DICOM format and scan resolution ≥0.2 mm has been demonstrated, necessitating the implementation of filtration or the repetition of scans.During the programme's planning stage, CBCT data were utilised to create models of tooth movements. GNN-based models analysed the relationships between teeth and periodontium, predicting movements with an accuracy of 0.25 mm along linear coordinates and 1.2° in inclination angle [1]. The application of this technology has been shown to reduce the duration of therapy by 10-15% and increase predictability by 25-30% [6]. Research conducted in the Journal of Orthodontic Science (2023) and the Progress in Orthodontics (2024) has demonstrated the efficacy of predicting the final tooth position with a margin of error of up to 0.25 mm/1.2°. The sensitivity of the model in predicting the need for tooth extraction was 70% [14].

In practice, the program adopted a personalised approach, demonstrating a 85% accuracy rate for forecasting jaw growth in childrenhood. Notably, surgery was averted in 30% of cases [9]. The accuracy of the procedure is reduced in a proportion of cases by biological factors, such as those relating to bone remodelling. This reduction in accuracy has been measured to occur in 10-20% of complex cases.In the national field of dentistry, an exemplary programme is "Determining the length of the anterior segment of dental arches by incisor width" (DGU 2023 2405, Tashkent State Dental Institute) [10]. The model calculated parameters and modelling, reducing analysis time from 8.6 to 3.1 minutes and increasing accuracy by 25-30%.

Results and discussion.

A thorough analysis of extant literature revealed that the degree of integration of artificial intelligence technologies into orthodontics exhibited significant variability, contingent on the specific clinical orientation. The highest level of implementation was observed in areas where AI allowed for the automation of routine processes and increased diagnostic accuracy. Consequently, the employment of automated cephalometric algorithms has been demonstrated to achieve accuracies of up to 95% in the determination of anatomical landmarks, thereby ensuring a 60-70% reduction in analysis time.

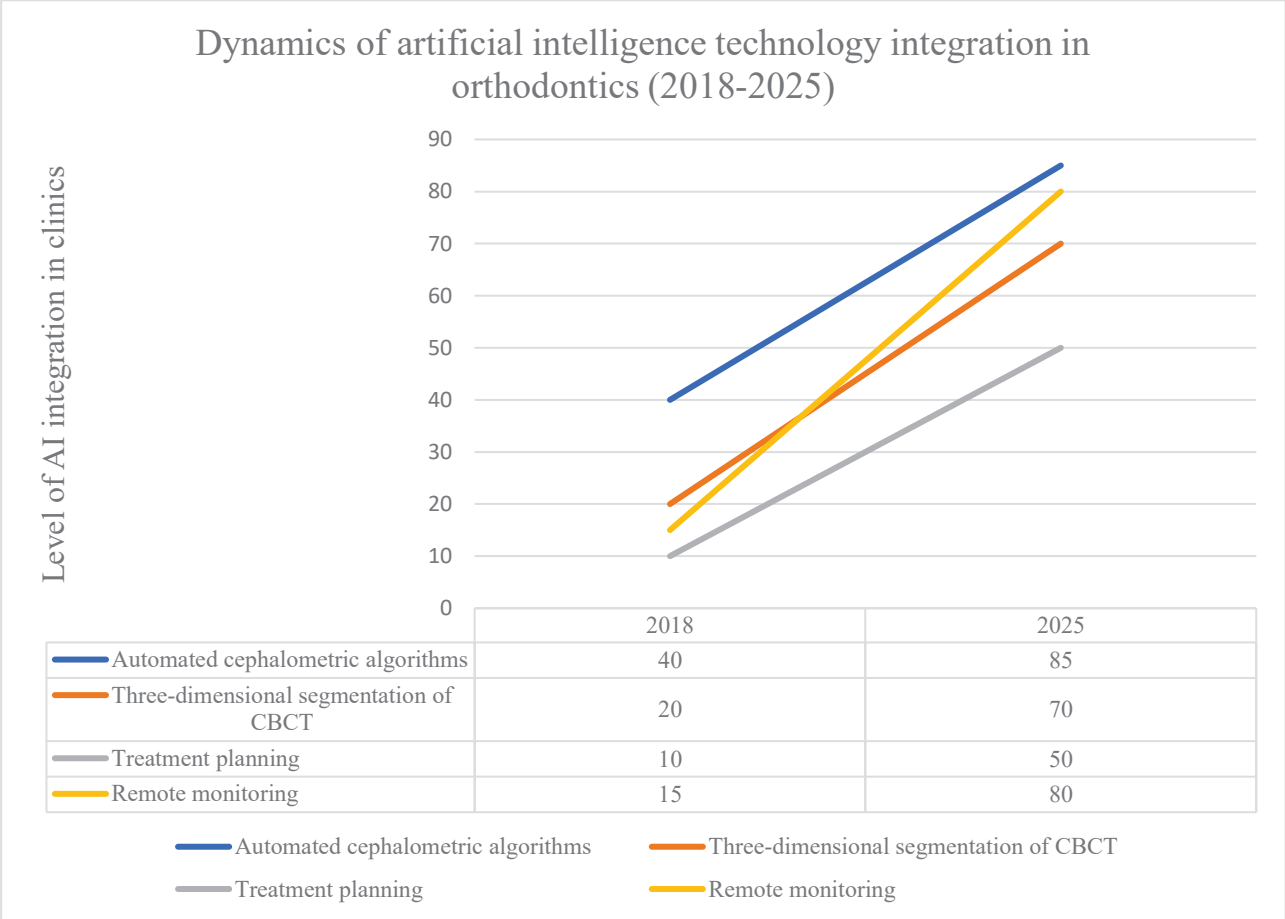
In the domain of three-dimensional segmentation of CBCT, the level of integration was evaluated as medium-high (60-70%): the implementation of neural network models enhanced the

quality of tissue reconstruction; nevertheless, the accuracy diminished by 10-15% in the presence of artefacts.

In the domain of remote monitoring, the integration of artificial intelligence has been demonstrated to curtail patient visits by 30-40%, while preserving diagnostic precision at 90%.

In the context of orthodontic treatment planning, artificial intelligence (AI) has demonstrated an accuracy of up to 85% in predicting the eventual position of teeth and jaw growth. However, in 10-20% of complex clinical cases, a decrease in accuracy has been observed, attributable to individual biological differences, such as the rate of bone remodelling [1,6].

Appendix 1. Dynamics of artificial intelligence technology integration in orthodontics (2018-2025)



Bibliometric analysis confirmed exponential growth in interest in the topic: the number of publications increased from 50 in 2018 to 300 in 2024. The primary research domains encompassed predictive analytics (60%) and personalised treatment (40%), reflecting the objective of enhancing the individualisation and objectivity of therapeutic interventions. Graph neural network-based models have been employed to analyse the relationships between teeth and periodontium, with a prediction of movements with an accuracy of 0.25 mm along linear coordinates and 1.2° in inclination angle [1].

A summary of the analysis demonstrated that the implementation of such programs has become a pivotal aspect of the digital transformation of orthodontics: systems automate routine tasks and transform approaches to diagnosis and planning. Mature areas of research include cephalometry and remote monitoring, which have been shown to reduce diagnostic time and increase reproducibility. Segmentation and planning have the potential to facilitate the integration of CBCT data, 3D modelling, and biomechanical predictions. The advantages of this approach are threefold: firstly, there

is an increase in accuracy; secondly, there is a reduction in subjectivity; and thirdly, there is a personalisation of therapy.Nevertheless, the findings suggest that there is a necessity to standardise data, eliminate algorithm bias, and train specialists. The role of AI is not to replace the physician; rather, it is to function as an enhancement tool, thereby ensuring objectivity, predictability of results, and adaptability of care. The integration of artificial intelligence with three-dimensional printing, bite models and aligners is set to create a digital, patient-centred approach.

Conclusion.

The conducted review of scientific literature confirms that artificial intelligence (AI) is transforming the diagnostic and treatment process by automating key processes such as image analysis, treatment planning and patient monitoring. This facilitates the optimisation of workflows, the minimisation of subjective errors, and the enhancement of therapy effectiveness.

Nevertheless, the implementation of AI necessitates meticulous oversight and standardisation to circumvent potential risks. Further research is required to investigate the potential for bias in algorithms resulting from imbalanced training data and the variability of patients' biological factors, including individual tissue response to treatment. This variability has the capacity to reduce accuracy by 10-20% in a number of cases.

It is recommended that AI is used exclusively as a supplement to the expertise of the medical practitioner, with an emphasis on the individualised selection of treatment methods, taking into account the patient's genetic and anatomical characteristics, and the prevention of complications such as inflammation or dental instability.

REFERENCES

1. Alqahtani K. A.Application of artificial intelligence in lateral cephalometric analysis: A systematic review // *Journal of Taibah University Medical Sciences*. — 2024. — DOI: 10.1016/j.jtumed.2024.02.001.

2. Aripova G., Nasimov E., Abdukadyrova N., Rasulova Sh., Masharipova S.Development of a digital method for arch width evaluation // *Journal of Oral Medicine and Craniofacial Research*. — 2023. — Vol. 4, No. 4. — DOI: 10.5281/zenodo.10048823.

3. Bichu Y. M., Hansa I., Bichu A. Y., et al.Applications of artificial intelligence and machine learning in orthodontics: A scoping review // *Progress in Orthodontics*. — 2021. — Vol. 22. — Art. 18. — DOI: 10.1186/s40510-021-00361-9.

4. Hendrickx J., Gracea R. S., Vanheers M., Winderickx N., Preda F., Shujaat S., Jacobs R.Can artificial intelligence-driven cephalometric analysis replace manual tracing? A systematic review and meta-analysis // *European Journal of Orthodontics*. — 2024. — Vol. 46, No. 4. — Art. cjae029. — DOI: 10.1093/ejo/cjae029.

5. Kiełczykowski M., Kamiński K., Perkowski K., Zadurska M., Czochrowska E.Application of artificial intelligence (AI) in cephalometric analysis: A narrative review // *Diagnostics*. — 2023. — Vol. 13, No. 16. — Art. 2640. — DOI: 10.3390/diagnostics13162640.

6. Kot W. Y., Au Yeung S. Y., Leung Y. Y., Li P. H., Yang W. F.Evolution of deep learning tooth segmentation from CT/CBCT images: A systematic review and meta-analysis // *BMC Oral Health*. — 2025. — DOI: 10.1186/s12903-025-05984-6.

7. Liu J., Zhang C., Shan B., Li H., Qiu H., Zhang H., Xia Z.Applications of artificial intelligence in orthodontics: A bibliometric and visualized analysis // *Clinical Oral Investigations*. — 2025. — Vol. 29. — DOI: 10.1007/s00784-025-06158-y.

8. Mercier J. P., Rossi C., Sanchez I. N., Pascual P. M., Rodriguez I. D., Tomas L.Reliability and accuracy of artificial intelligence-based software for cephalometric diagnosis: A diagnostic study // *BMC Oral Health*. — 2024. — Vol. 24. — Art. 5097. — DOI: 10.1186/s12903-024-05097-6.

9. Olawade D. B., Leena N., Egbon E., Rai J., Mohammed A. P. E. K., Oladapo B. I., Boussios S.AI-driven advancements in orthodontics for precision and patient outcomes // *Dentistry Journal*. — 2025. — Vol. 13, No. 5. — Art. 198. — DOI: 10.3390/dj13050198.

10. Rasulova Sh. R., Nasimov E. E., Aripova G. E., Dzhumaeva N. B., Kadirov R. Kh.Determination of the length of the anterior segment of dental arches based on incisor width : патент № DGU09945 Республики Узбекистан. — 2023.

11. Ruziyev Sh. D., Ruziyev B. D.Artificial intelligence integration in orthodontics and cephalometry: Optimizing diagnosis and treatment // *International Journal of Artificial Intelligence*. — 2025. — Vol. 5, No. 5. — P. 897–900.

12. Sola-Gracea R., et al.Artificial intelligence for orthodontic diagnosis and treatment planning: A scoping review // *Journal of Dentistry*. — 2025. — Vol. 152. — Art. 105442. — DOI: 10.1016/j.jdent.2024.105442.

13. Subramanian A. K., et al.Cephalometric analysis in orthodontics using artificial intelligence: A comprehensive review // *BioMed Research International*. — 2022. — Art. ID 1880113. — DOI: 10.1155/2022/1880113.

14. Tanikawa C., Yamashiro T.AI-enhanced orthodontic treatment planning: A scoping review on evidence-based clinical application with commercial software overview // *Journal of Dentistry*. — 2025. — DOI: 10.1016/j.jdent.2025.105585.