Original Research

https://doi.org/10.36377/ET-0125

Comparative analysis of dental parameters within 3D cephalometric analysis using artificial intelligence

Zurab S. Khabadze ✉, Ahmad Wehbe, Oleg S. Mordanov

Peoples' Friendship University of Russia named after Patrice Lumumba (RUDN University), Moscow, Russian Federation

✉ khabadze_zs@rudn.ru

Abstract

This study aimed to evaluate the comparability of three approaches to 3D cephalometric analysis: manual tracing in Invivo (Human Invivo), automated tracing using Diagnocat AI, and AI-assisted cephalometry in Invivo (AI Invivo). Materials and methods. A total of 30 CBCT scans were analyzed retrospectively, and measurements included overjet, overbite, incisor inclination, and interincisal angles. Statistical analysis comprised descriptive statistics, normality testing, ANOVA or Kruskal–Wallis tests with post-hoc comparisons, and intraclass correlation coefficient (ICC) evaluation. Pairwise differences were interpreted relative to pooled standard deviation (SD): <1 SD indicated comparability, 1–2 SD a moderate deviation, and ⩾2 SD a large deviation.Results demonstrated that for the majority of parameters, differences across all three methods were below one SD, confirming high comparability and reproducibility. No parameters exceeded the 2 SD threshold. Diagnocat AI provided clinically acceptable outcomes while offering practical advantages such as reduced operator variability, faster processing time, and lower cost compared to manual tracing and AI Invivo. Conclusion. These findings suggest that both Diagnocat AI and AI Invivo may serve as reliable alternatives or adjuncts to manual cephalometry in orthodontic practice.

Keywords: 3D cephalometry, artificial intelligence, CBCT, Diagnocat, orthodontics, cephalometric analysis

Article info: received – 02.08.2025; revised – 03.09.2025; accepted – 15.09.2025

Conflict of interest: The authors report no conflict of interest.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Khabadze Z.S., Wehbe A., Mordanov O.S. Comparative analysis of dental parameters within 3D cephalometric analysis using artificial intelligence. *Endodontics Today*. 2025;23(4):511–518. https://doi.org/10.36377/ET-0125

Сравнительный анализ дентальных параметров в рамках 3D-цефалометрического анализа с помощью искусственного интеллекта

З.С. Хабадзе ✉, А. Вехби, О.С. Морданов

Российский университет дружбы народов им. Патриса Лумумбы, г. Москва, Российская Федерация

✉ khabadze_zs@rudn.ru

Резюме

Целью данного исследования было сравнение трех подходов к 3D-цефалометрическому анализу: ручная трассировка в программе Invivo (Human Invivo), автоматизированный анализ с использованием Diagnocat AI и автоматическая цефалометрия в Invivo (AI Invivo). Материалы и методы. В ретроспективное исследование были включены 30 КЛКТ-сканов; оценивались такие параметры, как оверджет, овербайт, наклон резцов и межрезцовые углы. Для статистической обработки использовались описательная статистика, тест Шапиро–Уилка, однофакторный ANOVA или тест Краскела–Уоллиса с пост-hoc анализом, а также коэффициент внутриклассовой корреляции (ICC). Различия между методами интерпретировались относительно среднего стандартного отклонения (SD): <1 SD – сопоставимость, 1–2 SD – умеренное расхождение, ⩾2 SD – значительное расхождение. Результаты показали, что для большинства параметров различия между методами не превышали одного SD, что подтверждает высокую сопоставимость и воспроизводимость результатов. Ни один параметр не превысил порог в 2 SD. Diagnocat AI продемонстрировал клинически приемлемые результаты и обладал дополнительными преимуществами – снижением зависимости от оператора, сокращением времени анализа и меньшей стоимостью по сравнению с ручной трассировкой и AI Invivo. Вывод. Полученные данные позволяют рассматривать Diagnocat AI и AI Invivo как надежные альтернативы или дополнения к традиционной ручной цефалометрии в ортодонтической практике.

Ключевые слова: 3D-цефалометрия, искусственный интеллект, КЛКТ, Diagnocat, ортодонтия, цефалометрический анализ

Информация о статье: поступила – 02.08.2025; исправлена – 03.09.2025; принята – 15.09.2025

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Хабадзе З.С., Вехби А., Морданов О.С. Сравнительный анализ дентальных параметров в рамках 3D-цефалометрического анализа с помощью искусственного интеллекта. *Эндодонтия Today.* 2025;23(4):511–518. https://doi.org/10.36377/ET-0125

INTRODUCTION

From its early development, artificial intelligence (AI) has driven substantial progress, transforming many aspects of daily life, including healthcare [1; 2]. More recently, AI has enabled the rise of personalized medicine, allowing for more accurate evaluation of disease predisposition, precise diagnoses, and tailored treatment planning for each individual [3]. In dentistry, AI is applied to a wide range of tasks, such as tooth numbering, assessing the spatial relation between third molars and the mandibular canal, implant planning, diagnosing periapical pathologies, detecting caries, evaluating osteoporotic changes, and identifying jaw tumors [4].

AI has become particularly important in the processing and interpretation of Cone Beam Computed Tomography (CBCT) in dental practice [5]. Advanced algorithms, such as Diagnocat, are designed to perform both coarse and detailed segmentation of teeth in CBCT scans, making them highly effective for managing extensive datasets [6]. The Diagnocat system can efficiently process CBCT images in DICOM format, ensuring seamless data exchange [7]. AI-based dental imaging software significantly accelerates data analysis and enhances processing efficiency [8]. CBCT, as a 3D imaging technique, is widely implemented in dentistry for multiple purposes, including implant placement, orthodontic treatment planning, and root canal therapy [9]. Currently, much scientific attention is focused on AI-driven approaches that aim to automate landmark identification in CBCT scans [10].

Cephalometric analysis is a quantitative diagnostic method widely employed by orthodontists, prosthodontists, as well as maxillofacial and orthognathic surgeons to evaluate skeletal and dentoalveolar relationships, morphometric parameters, and growth patterns. Since its introduction in 1931, this technique has undergone major advancements, integrating the latest innovations in orthodontic radiology and diagnostics [11]. The method is based on linear and angular measurements taken from two-dimensional (2D) radiographs of the skull, producing an individualized cephalogram for each patient [12]. Conventional cephalometric landmarks are identified on skeletal structures (anterior and posterior cranial base, maxilla, and mandible), on teeth (molars and incisors), and on soft tissues (nose and chin). By calculating distances and angles between these reference points and axes, clinicians can classify patients according to their skeletal, dental, and profile characteristics. Despite progress in technology, manual tracing of cephalometric points on lateral, frontal, and axial 2D radiographs continues to be considered the gold standard. The main challenges in this approach are the time required, the high level of expertise, and the intra- and inter-operator variability in landmark identification [13].

Although specialized software is now commonly used to perform cephalometric measurements, landmark tracing still needs to be carried out manually by an orthodontic expert [14]. The reliability of the analysis strongly depends on the clinician's skill and even on situational factors, which can result in inconsistencies [15]. The lack of reproducibility in manual landmark identification poses a serious issue, since inaccurate tracing can lead to incorrect orthodontic treatment decisions. Therefore, the development of fully automated, robust methods for detecting cephalometric points remains highly desirable. AI algorithms provide promising opportunities to support orthodontists in routine practice, potentially improving both efficiency and accuracy [16].

To date, only a limited number of studies have applied convolutional neural networks (CNNs) for automated 3D cephalometric analysis. While initial results have been encouraging, these studies have also demonstrated notable methodological shortcomings [17]. Thus, firm conclusions about the practical application of such algorithms remain premature.

The purpose of the present study is to compare dental parameters as a part of 3D cephalometric analysis conducted with the aid of AI to that performed manually by a specialist orthodontist. The null hypothesis states that there is no statistically significant difference between 3D cephalometric analysis performed by an AI-powered virtual assistant and that conducted manually by an orthodontic specialist.

MATERIALS AND METHODS

This investigation was approved by the Bioethics Committee of RUDN University (protocol №12, March 17, 2024). The study was carried out using retrospective and registry data; thus, it did not involve any direct human experimentation, the use of biological samples, or the recruitment of patients specifically for research purposes.

Study design and patient selection

CBCT scans were analyzed from 30 consecutive patients, aged between 18 and 50 years (13 male and 17 female), who were examined at a local diagnostic center. The dataset was annotated by two experts: a dental and maxillofacial radiologist with extensive clinical experience in surgical procedures and full-mouth rehabilitation, and an orthodontist, both of whom identified cephalometric landmarks. To ensure calibration, each specialist performed the tracings twice, with a 7-day interval between sessions. Cases were excluded if inter-observer differences exceeded half of the standard deviation, or if intra-observer variability for a single examiner was greater than half of the standard deviation. After these checks, mean values were calculated for the final analysis.

The inclusion criteria specified patients with well-controlled systemic conditions, those requiring both cephalometric radiographs and CBCT, absence of maxillofacial deformities, fully erupted incisors and first molars, and no prior orthodontic treatment.

All CBCT scans were acquired using the GALILEOS Comfort unit (Sirona Dental Systems GmbH, Bensheim, Germany) under the following parameters: 98 kV tube voltage, 5 mAs tube current, 14-second scanning time, a field of view (FOV) of 15 × 15 cm, and an isotropic voxel size of 0.25 mm. During acquisition, patients were instructed to remain in habitual occlusion with lips and tongue relaxed, while their heads were stabilized using head and chin supports, avoiding unnecessary pressure.

3D Cephalometric Analysis

The cephalometric evaluation was carried out using two different approaches. The first consisted of manual landmark tracing, performed in Invivo 6 software (Anatomage Inc., Santa Clara, CA). To maintain consistency, a predetermined number of landmarks was selected for all measurements. Initial alignment of CBCT images was based on the following anatomical reference points: Ba, Or R, Or L, Po R, and Na. Once aligned, the complete set of landmarks was traced according to established definitions [18; 19].

The second approach utilized AI-based cephalometric analysis, generated through the Diagnocat system (Diagnocat Ltd., San Francisco, CA, USA). Diagnocat produces orthodontic reports using a pipeline composed of multiple pre-trained fully convolutional neural networks, supplemented with algorithmic slice extraction and AI-driven landmark identification (Fig. 2). The software incorporates internally modified 3D U-Net–based semantic segmentation networks to deliver voxel-accurate segmentation of teeth and surrounding anatomical structures [20]. Cephalometric measurements obtained are summarized in Table 1. Each dataset was analyzed independently, with the clinicians blinded to the AI results, to evaluate the diagnostic reliability of the AI-generated reports.

The third approach applied the AI module integrated into Invivo 7 (Anatomage Inc., Santa Clara, CA), which provides automated cephalometric landmark detection. The software combines machine learning algorithms with built-in cephalometric templates to generate measurements directly from CBCT data. This method was tested under the same inclusion and exclusion criteria as the other two, and results were compared separately.

The cephalometric measurements are detailed in Table 1. Each result was evaluated separately and independently, without any prior knowledge of the AI results, to determine the reliability of the AI-generated diagnostic reports.

Table 1. The measurements and norms of compared parameters (values are taken from the current Diagnocat orthoreport)

Таблица 1. Измерения и нормы сравниваемых параметров (значения взяты из текущего ортодонтического отчета Diagnocat)

Variable	Norm	SD
Overjet	3 mm	1
Overbite	3 mm	1
Upper incisor U1-SN R	105°	2
Upper incisor U1-SN L	105°	2
Lower incisor L1-MP R	90°	5
Lower incisor L1-MP L	90°	5
Interincisal angle U1-L1(R)	130°	6
Interincisal angle U1-L1(L)	130°	6

Statistical analysis

Statistical analysis was performed using the R language for statistical computing. Descriptive statistics included minimum, maximum, median, first (Q1) and third (Q3) quartiles, mean, and standard deviation (SD). Normality of distribution was assessed using the Shapiro–Wilk test and Q–Q plots. For comparisons between the three methods (Human Invivo, Diagnocat AI, and AI Invivo), one-way ANOVA was applied for normally distributed variables, followed by Tukey's HSD post-hoc test. For non-normally distributed variables, the Kruskal–Wallis test was applied, followed by pairwise comparisons with appropriate corrections. Agreement among the three methods was assessed using the Intraclass Correlation Coefficient (ICC, two-way random effects model, absolute agreement).

Differences between methods were further evaluated in relation to the pooled SD:

– differences within one SD were considered comparable;

– differences of one to two SD indicated moderate deviation;

– differences exceeding two SD indicated large deviation.

To visualize these comparisons, difference plots were generated for each parameter. The plots were color-coded according to the deviation thresholds: green zone ($\Delta < 1$ SD, comparable), yellow zone ($\Delta = 1–2$ SD, moderate deviation), and red zone ($\Delta \geqslant 2$ SD, large deviation). A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 30 CBCT scans were analyzed using three methods: Human Invivo (manual tracing), Diagnocat AI, and AI Invivo.

Descriptive statistics (minimum, maximum, quartiles, mean, and SD) were calculated for each parameter across the three methods.

Comparative analysis

The mean differences (Δ) between each pair of methods were compared against the pooled standard deviation (SD). The interpretation criteria were as follows:

– Comparable (<1 SD): differences within one standard deviation;

– Deviation (1–2 SD): moderate discrepancy;

– Large deviation (⩾2 SD): clinically significant discrepancy.

The summary table with pairwise comparisons, ΔMean, SD, and interpretation is presented in Table 2.

Graphical analysis

For each cephalometric parameter, difference plots were constructed (Fig. 1–5).

The plots are color-coded according to the deviation thresholds:

– Green zone – differences within one SD (methods are comparable);

– Yellow zone – differences between one and two SD (moderate discrepancy);

– Red zone – differences above two SD (large discrepancy).

Table 2. Comporation of methods

Таблица 2. Сравнение методов

Parameter	Comparison	ΔMean	SD	Interpretation
Overjet	Human Invivo vs Diagnocat	0.03	1.65	Comparable (<1 SD)
Overjet	Human Invivo vs AI Invivo	–0.26	1.65	Comparable (<1 SD)
Overjet	Diagnocat vs AI Invivo	–0.28	1.75	Comparable (<1 SD)
Overbite	Human Invivo vs Diagnocat	–0.36	1.53	Comparable (<1 SD)
Overbite	Human Invivo vs AI Invivo	0.23	1.49	Comparable (<1 SD)
Overbite	Diagnocat vs AI Invivo	0.59	1.49	Comparable (<1 SD)
U1-SN R	Human Invivo vs Diagnocat	–1.16	9.97	Comparable (<1 SD)
U1-SN R	Human Invivo vs AI Invivo	–2.15	8.94	Comparable (<1 SD)
U1-SN R	Diagnocat vs AI Invivo	–1.09	9.06	Comparable (<1 SD)
U1-SN L	Human Invivo vs Diagnocat	–1.74	9.77	Comparable (<1 SD)
U1-SN L	Human Invivo vs AI Invivo	–1.49	12.87	Comparable (<1 SD)
U1-SN L	Diagnocat vs AI Invivo	0.0	11.67	Comparable (<1 SD)
L1-MP R	Human Invivo vs Diagnocat	–1.32	10.44	Comparable (<1 SD)
L1-MP R	Human Invivo vs AI Invivo	2.31	10.1	Comparable (<1 SD)
L1-MP R	Diagnocat vs AI Invivo	3.56	9.85	Comparable (<1 SD)
L1-MP L	Human Invivo vs Diagnocat	–1.22	9.54	Comparable (<1 SD)
L1-MP L	Human Invivo vs AI Invivo	–0.29	12.5	Comparable (<1 SD)
L1-MP L	Diagnocat vs AI Invivo	0.0	10.96	Comparable (<1 SD)
U1-L1(R)	Human Invivo vs Diagnocat	1.12	15.32	Comparable (<1 SD)
U1-L1(R)	Human Invivo vs AI Invivo	0.23	14.0	Comparable (<1 SD)
U1-L1(R)	Diagnocat vs AI Invivo	–0.72	14.16	Comparable (<1 SD)
U1-L1(L)	Human Invivo vs Diagnocat	1.58	13.47	Comparable (<1 SD)
U1-L1(L)	Human Invivo vs AI Invivo	1.84	5.22	Comparable (<1 SD)
U1-L1(L)	Diagnocat vs AI Invivo	0.0	4.74	Comparable (<1 SD)

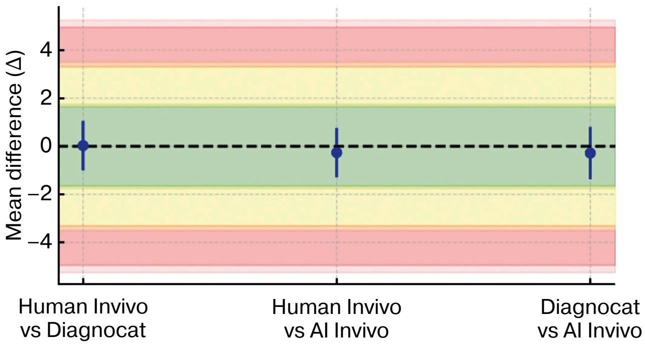


Fig. 1. Difference plot for Overjet

Рис. 1. График различий для сагиттальной щели

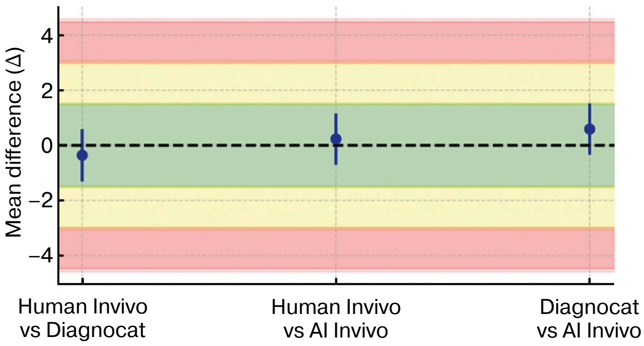
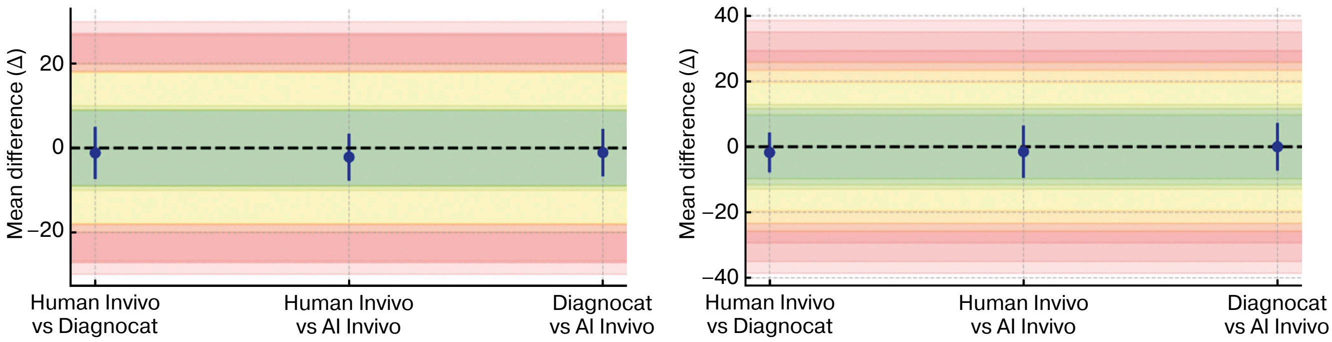


Fig. 2. Difference plot for Overbite

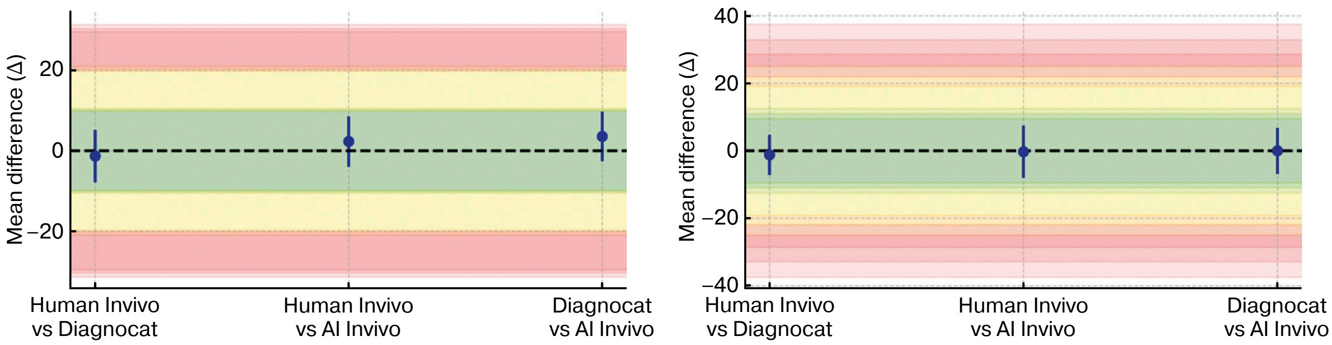
Рис. 2. График различий для вертикального резцового перекрытия



A **B**

Fig. 3. Difference plot for U1-SN: *A* – right; *B* – left

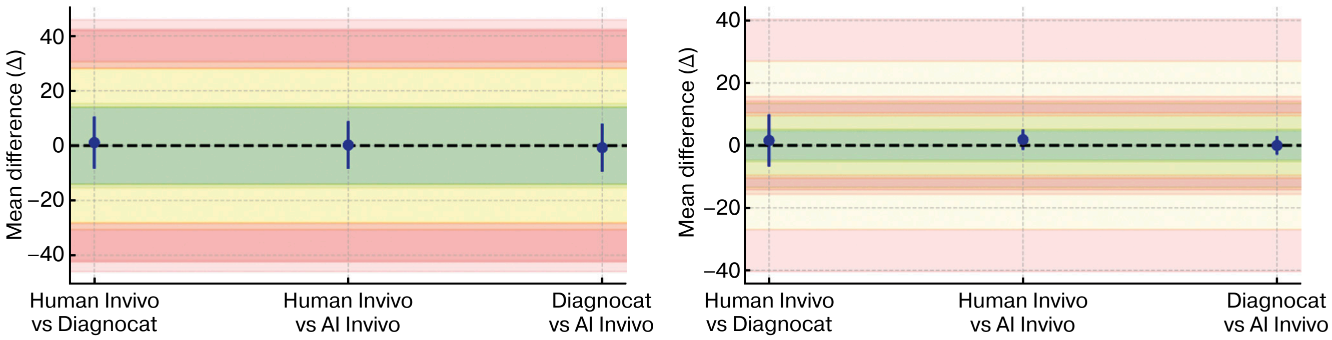
Рис. 3. График различий для U1-SN: *A* – справа; *B* – слева



A **B**

Fig. 4. Difference plot for L1-MP: *A* – right; *B* – left

Рис. 4. График различий для L1-MP: *A* – справа; *B* – слева



A **B**

Fig. 5. Difference plot for U1-L1: *A* – right; *B* – left

Рис. 5. График различий для U1–L1: *A* – справа; *B* – слева

Most parameters showed differences within one SD, indicating a high level of agreement between the three methods. Only a limited number of variables demonstrated deviations exceeding one SD, and very few parameters exceeded the two-SD threshold.

Agreement between methods

The overall consistency across the three methods was confirmed by Intraclass Correlation Coefficient (ICC) analysis, with the majority of parameters showing good to excellent agreement (ICC > 0.75).

DISCUSSION

Cone Beam Computed Tomography (CBCT) has become increasingly important in orthodontics because it can generate high-resolution three-dimensional (3D) representations of dental and skeletal structures, soft tissues, neural pathways, and bone morphology [20]. The present study compared automated 3D cephalometric analysis using the Diagnocat AI system with manual tracings performed in Invivo 6, and, additionally, with automated cephalometric landmark detection available in Invivo 7. Recent investigations have repeatedly demonstrated the superior precision of 3D cephalometric analysis compared to traditional two-dimensional (2D) approaches [21]. Furthermore, deep learning (DL) algorithms have shown improved performance over conventional machine learning (ML) approaches in bioimaging applications [22], which has encouraged the development of DL-based algorithms for automated landmark identification in 3D datasets.

Several systematic reviews and meta-analyses have examined the use of AI for 3D cephalometric analysis in orthodontics [17; 23]. Across these works, DL-based algorithms consistently outperformed other ML techniques in the accuracy of landmark detection. Despite these promising advances, most of the reviewed studies did not include Diagnocat or Invivo's newer AI-assisted functionalities, and many focused only on landmark localization without assessing cephalometric parameter accuracy or providing rigorous statistical validation [24]. Cephalometric analysis inherently simplifies a 3D craniofacial structure into a 2D representation, which introduces potential projection and measurement errors [25]. However, the null hypothesis – that no difference exists between AI-based and manual analysis – was accepted.

In terms of incisor inclination, the differences were unilateral. Kunz et al. [26] compared AI-based cephalometric analyses with manual expert tracings and found that upper incisor angulation demonstrated larger deviations in AI predictions (absolute mean difference 2.18°) compared with inter-examiner variability (1.50°). This highlights the clinical importance of precise landmark placement for orthodontic and orthognathic treatment planning. Chen et al. [27] also reported that clinical experience strongly influences the ability to consistently identify cephalometric points, with more experienced clinicians demonstrating greater accuracy [28]. Even so, errors remain possible, as demonstrated by Zamrik et al. [29], who noted inaccuracies in measuring the U1-A point.

When evaluating software-assisted approaches, several studies have reported no major differences between program-generated tracings and those performed by experts [30]. Kunz et al. [26] even argued that the comparison is inherently "unfair", since human experts themselves define the gold standard. In the present study, Invivo 7's integrated AI module demonstrated performance closer to manual tracings than Diagnocat for certain parameters, suggesting that hybrid systems – where traditional cephalometric software incorporates AI functions – may offer improved reliability.

CONCLUSION

The comparative analysis of Human Invivo, Diagnocat AI, and AI Invivo demonstrated that all evaluated parameters, including overjet and overbite, showed mean differences smaller than one standard deviation across the methods. This indicates strong comparability and reproducibility between manual tracing and AI-based approaches, supporting the clinical interchangeability of these methods for core cephalometric measurements.

No parameters exceeded the threshold of one standard deviation, and none fell into the categories of moderate or large deviation. These findings confirm that both Diagnocat AI and AI Invivo can be reliably applied alongside manual cephalometry in routine orthodontic diagnostics, ensuring accuracy and consistency in treatment planning.

In addition to the high level of agreement with manual cephalometry, Diagnocat AI offers practical advantages. Compared with both Human Invivo and AI Invivo, Diagnocat substantially reduces the time required for analysis and eliminates operator-dependent variability. Moreover, its lower cost and automated workflow make it an efficient and accessible tool for routine orthodontic practice, especially in high-volume clinical environments where speed and reproducibility are crucial.

REFERENCES / СПИСОК ЛИТЕРАТУРЫ

1. Sun M., Chai Y., Chai G., Zheng X. Fully automatic robot-assisted surgery for mandibular angle split osteotomy. *J Craniofac Surg*. 2020;31(2):336–339. https://doi.org/10.1097/SCS.0000000000005587
2. Rahimy E., Wilson J., Tsao T.C., Schwartz S., Hubschman J.P. Robot-assisted intraocular surgery: development of the IRISS and feasibility studies in an animal model. *Eye*. 2013;27(8):972–978. https://doi.org/10.1038/eye.2013.105
3. Castillo D., Galvez J.M., Herrera L.J., Rojas F., Valenzuela O., Caba O. et al. Leukemia multiclass assessment and classification from Microarray and RNA-seq technologies integration at gene expression level. *PLoS ONE*. 2019;14(2):e0212127. https://doi.org/10.1371/journal.pone.0212127
4. Orhan K., Aktuna Belgin C., Manulis D., Golitsyna M., Bayrak S., Aksoy S. et al. Determining the reliability of diagnosis and treatment using artificial intelligence software with panoramic radiographs. *Imaging Sci Dent*. 2023;53(3):199–208. https://doi.org/10.5624/isd.20230109
5. Thurzo A., Urbanová W., Novák B., Czako L., Siebert T., Stano P. et al. Where is the artificial intelligence applied in dentistry? Systematic review and literature analysis. *Healthcare*. 2022;10(7):1269. https://doi.org/10.3390/healthcare10071269
6. Ezhov M., Gusarev M., Golitsyna M., Yates J.M., Kushnerev E., Tamimi D. et al. Clinically applicable artificial intelligence system for dental diagnosis with CBCT. *Sci Rep*. 2021;11(1):15006. https://doi.org/10.1038/s41598-021-94093-9 (Erratum in: *Sci Rep*. 2021;11(1):22217. https://doi.org/10.1038/s41598-021-01678-5)
7. Orhan K., Shamshiev M., Ezhov M., Plaksin A., Kurbanova A., Ünsal G. 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(1):11863. https://doi.org/10.1038/s41598-022-15920-1

8. Urban R., Haluzová S., Strunga M., Surovková J., Lifková M., Tomášik J., Thurzo A. AI-assisted CBCT data management in modern dental practice: benefits, limitations and innovations. *Electronics*. 2023;12(7):1710. https://doi.org/10.3390/electronics12071710

9. Zhang C., Fan L., Zhang S., Zhao J., Gu Y. Deep learning based dental implant failure prediction from periapical and panoramic films. *Quant Imaging Med Surg*. 2023;13(2):935–945. https://doi.org/10.21037/qims-22-457

10. Mureșanu S., Almășan O., Hedeșiu M., Dioșan L., Dinu C., Jacobs R. Artificial intelligence models for clinical usage in dentistry with a focus on dentomaxillofacial CBCT: a systematic review. *Oral Radiol*. 2023;39(1):18–40. https://doi.org/10.1007/s11282-022-00660-9

11. Hwang H.W., Moon J.H., Kim M.G., Donatelli R.E., Lee S.J. Evaluation of automated cephalometric analysis based on the latest deep learning method. *Angle Orthod*. 2021;91(3):329–335. https://doi.org/10.2319/021220-100.1

12. Hans M.G., Palomo J.M., Valiathan M. History of imaging in orthodontics from Broadbent to cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2015;148(6):914–921. https://doi.org/10.1016/j.ajodo.2015.09.007

13. Farronato G., Salvadori S., Nolet F., Zoia A., Farronato D. Assessment of inter- and intra-operator cephalometric tracings on cone beam CT radiographs: comparison of the precision of the cone beam CT versus the latero-lateral radiograph tracing. *Prog Orthod*. 2014;15:1. https://doi.org/10.1186/2196-1042-15-1

14. Nishimoto S., Sotsuka Y., Kawai K., Ishise H., Kakibuchi M. Personal computer-based cephalometric landmark detection with deep learning, using cephalograms on the internet. *J Craniofac Surg*. 2019;30(1):91–95. https://doi.org/10.1097/SCS.0000000000004901

15. Wang C.W., Huang C.T., Hsieh M.C., Li C.H., Chang S.W., Li W.C. et al. Evaluation and comparison of anatomical landmark detection methods for cephalometric X-ray images: A grand challenge. *IEEE Trans Med Imaging*. 2015;34(9):1890–1900. https://doi.org/10.1109/TMI.2015.2412951

16. Arık S.Ö., Ibragimov B., Xing L. Fully automated quantitative cephalometry using convolutional neural networks. *J Med Imaging*. 2017;4(1):014501. https://doi.org/10.1117/1.JMI.4.1.014501

17. Serafin M., Baldini B., Cabitza F., Carrafiello G., Baselli G., Del Fabbro M. et al. Accuracy of automated 3D cephalometric landmarks by deep learning algorithms: systematic review and meta-analysis. *Radiol Med*. 2023;128(5):544–555. https://doi.org/10.1007/s11547-023-01629-2

18. Zamora N., Llamas J.M., Cibrián R., Gandia J.L., Paredes V. A study on the reproducibility of cephalometric landmarks when undertaking a three-dimensional (3D) cephalometric analysis. *Med Oral Patol Oral Cir Bucal*. 2012;17(4):e678–e688. https://doi.org/10.4317/medoral.17721

19. Phulari B. *An atlas on cephalometric landmarks*. London: JP Medical Ltd; 2013. 213 p.

20. Isensee F., Kickingereder P., Wick W., Bendszus M., Maier-Hein K.H. Brain tumor segmentation and radiomics survival prediction: contribution to the BRATS 2017 challenge. In: In: Crimi A., Bakas S., Kuijf H., Menze B., Reyes M. (eds) *Brainlesion: Glioma, multiple sclerosis, stroke and traumatic brain injuries. BrainLes 2017. Lecture Notes in Computer Science, vol 10670*. Springer, Cham; 2017, pp. 287–297. https://doi.org/10.1007/978-3-319-75238-9_25

21. Gazimagomedova A.Sh., Vardanyan M.A., Drobysheva N.S. Comparative evaluation of methods fordetermining the width of the upper jaw in growing patients. *Endodontics Today*. 2023;21(3):231–237. (In Russ.) https://doi.org/10.36377/1683-2981-2023-21-3-231-237
Газимагомедова А.Ш., Варданян М.А., Дробышева Н.С. Сравнительная оценка методов определения ширины верхней челюсти у растущих пациентов. *Эндодонтия Today*. 2023;21(3):231–237. https://doi.org/10.36377/1683-2981-2023-21-3-231-237

22. Sam A., Currie K., Oh H., Flores-Mir C., Lagravére-Vich M. Reliability of different three-dimensional cephalometric landmarks in cone-beam computed tomography: A systematic review. *Angle Orthod*. 2019;89(2):317–332. https://doi.org/10.2319/042018-302.1

23. Zemouri R., Zerhouni N., Racoceanu D. Deep learning in the biomedical applications: Recent and future status. *Appl Sci*. 2019;9(8):1526. https://doi.org/10.3390/app9081526

24. Alsubai S. A critical review on the 3D cephalometric analysis using machine learning. *Computers*. 2022;11(11):154. https://doi.org/10.3390/computers11110154

25. Das B.R., Jain P., Modi N., Soni P., Datta D., De A.. SNA and SNB measurements: a comparative assessment between measurements in conventional 2D cephalogram and 3D cone-beam computed tomography-generated values. *Int J Oral Care Res*. 2021;9(3):71–75. https://doi.org/10.4103/INJO.INJO_20_21

26. Kunz F., Stellzig-Eisenhauer A., Zeman F., Boldt J. Artificial intelligence in orthodontics: Evaluation of a fully automated cephalometric analysis using a customized convolutional neural network. *J Orofac Orthop*. 2020;81(1):52–68. https://doi.org/10.1007/s00056-019-00203-8

26. Chen Z., Mo S., Fan X., You Y., Ye G., Zhou N. A meta-analysis and systematic review comparing the effectiveness of traditional and virtual surgical planning for orthognathic surgery: Based on randomized clinical trials. *J Oral Maxillofac Surg*. 2021;79(2):471.e1–471.e19. https://doi.org/10.1016/j.joms.2020.09.005

28. Akhare P.J., Dagab A.M., Alle R.S., Shenoyd U., Garla V. Comparison of landmark identification and linear and angular measurements in conventional and digital cephalometry. *Int J Comput Dent*. 2013;16(3):241–254.

29. Zamrik O.M., İşeri H. The reliability and reproducibility of an Android cephalometric smartphone application in comparison with the conventional method. *Angle Orthod*. 2021;91(2):236–242. https://doi.org/10.2319/042320-345.1

30. Smołka P., Nelke K., Struzik N., Wiśniewska K., Kiryk S., Kensy J. et al. Discrepancies in cephalometric analysis results between orthodontists and radiologists and artificial intelligence: A systematic review. *Appl Sci*. 2024;14(12):4972. https://doi.org/10.3390/app14124972

INFORMATION ABOUT THE AUTHORS

Zurab S. Khabadze – Dr. Sci. (Med.), Professor, Head of the Department of Therapeutic Dentistry, Medical Institute, Peoples' Friendship University of Russia named after Patrice Lumumba (RUDN University), 6 Miklukho-Maklaya Str., Moscow 117198, Russian Federation; https://orcid.org/0000-0002-7257-5503

Ahmad Wehbe – Assistant, Department of Therapeutic Dentistry, Medical Institute, Peoples' Friendship University of Russia named after Patrice Lumumba (RUDN University), 6 Miklukho-Maklaya Str., Moscow 117198, Russian Federation; https://orcid.org/0009-0009-5325-3793

Oleg S. Mordanov – Cand. Sci. (Med.), Assistant, Department of Therapeutic Dentistry, Medical Institute, Peoples' Friendship University of Russia named after Patrice Lumumba (RUDN University), 6 Miklukho-Maklaya Str., Moscow 117198, Russian Federation; https://orcid.org/0000-0002-9878-7045

ИНФОРМАЦИЯ ОБ АВТОРАХ

Хабадзе Зураб Суликоевич – д.м.н., профессор, заведующий кафедрой терапевтической стоматологии Медицинского института, ФГАОУ ВО «Российский университет дружбы народов им. Патриса Лумумбы», 117198, Российская Федерация, г. Москва, ул. Миклухо-Маклая, д. 6; https://orcid.org/0000-0002-7257-5503

Вехби Ахмад – ассистент кафедры терапевтической стоматологии Медицинского института, ФГАОУ ВО «Российский университет дружбы народов им. Патриса Лумумбы», 117198, Российская Федерация, г. Москва, ул. Миклухо-Маклая, д. 6; https://orcid.org/0009-0009-5325-3793

Морданов Олег Сергеевич – к.м.н., ассистент кафедры терапевтической стоматологии Медицинского института, ФГАОУ ВО «Российский университет дружбы народов им. Патриса Лумумбы», 117198, Российская Федерация, г. Москва, ул. Миклухо-Маклая, д. 6; https://orcid.org/0000-0002-9878-7045

AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования