AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

ISSN NUMBER: 2692 - 5206 Volume 5,October ,2025

UDC: 616.314.2/.3-073.75:004.94:005.6

MODERN METHODS FOR OPTIMIZING AND IMPROVING GNATOMETRIC ANALYSIS BASED ON TELEROENTGENOGRAPHY DATA

Raimjonov Rustambek Ravshanbek ugli
Department of Orthopedic Dentistry and Orthodontics,
Andijan State Medical Institute
Uzbekistan, Andijan

RELEVANCE: The success of treatment in orthodontics and maxillofacial surgery is directly dependent on accurate diagnosis and meticulous planning. Cephalometric analysis of teleroentgenography (TRG) data serves as the fundamental basis for this process, enabling the assessment of complex interrelationships of facial and skeletal structures. However, traditional manual tracing methods are not only time-consuming but are also susceptible to subjective errors contingent on the operator's experience. These inaccuracies can, in turn, lead to an incorrect treatment plan, a failure to achieve expected outcomes, and even negative consequences for the patient's health. The rapid development of digital technologies, particularly automated analysis systems based on artificial intelligence (AI), is revolutionizing gnatometric analysis. These systems have the potential to drastically increase the accuracy, speed, and, most importantly, the reproducibility of the analysis, thereby standardizing the diagnostic process and minimizing human-factor-related errors. Optimizing and widely implementing these modern methods into clinical practice not only improves diagnostic quality but also allows for more reliable prediction of treatment outcomes, virtual modeling of surgical interventions, and enhancement of the educational process. Therefore, the in-depth study and refinement of these technologies represent one of the most urgent tasks in modern dentistry.

Keywords: teleroentgenography, cephalometric analysis, gnatometric analysis, orthodontics, digital dentistry, artificial intelligence, automated landmark identification.

СОВРЕМЕННЫЕ МЕТОДЫ ОПТИМИЗАЦИИ И СОВЕРШЕНСТВОВАНИЯ ГНАТОМЕТРИЧЕСКОГО АНАЛИЗА НА ОСНОВЕ ДАННЫХ ТЕЛЕРЕНТГЕНОГРАФИИ

АКТУАЛЬНОСТЬ: Успех лечения в ортодонтии и челюстно-лицевой хирургии напрямую зависит от точности диагностики и тщательного планирования. Цефалометрический анализ данных телерентгенографии (ТРГ) является фундаментальной основой этого процесса, позволяя оценить сложные взаимосвязи лицевых и скелетных структур. Однако традиционные методы ручной трассировки не только трудоемки, но и подвержены субъективным ошибкам, зависящим от опыта оператора. Эти ошибки, в свою очередь, могут привести к неверному плану лечения, недостижению ожидаемых результатов и даже к негативным последствиям для здоровья пациента. Стремительное развитие цифровых технологий, особенно автоматизированных систем анализа на основе искусственного интеллекта (ИИ), производит революцию в гнатометрическом анализе. Эти системы обладают потенциалом кардинально повысить точность, скорость и, что наиболее важно, воспроизводимость анализа, тем самым стандартизируя диагностический процесс и минимизируя ошибки, связанные с человеческим фактором. Оптимизация и широкое

внедрение этих современных методов в клиническую практику не только улучшают качество диагностики, но и позволяют более надежно прогнозировать результаты лечения, виртуально моделировать хирургические вмешательства и совершенствовать образовательный процесс. Таким образом, углубленное изучение и совершенствование данных технологий является одной из самых актуальных задач современной стоматологии.
Ключевые слова: телерентгенография, цефалометрический анализ, гнатометрический анализ, ортодонтия, цифровая стоматология, искусственный интеллект, автоматическое определение ориентиров.

TELERENTGENOGRAFIYA MA'LUMOTLARI ASOSIDA GNATOMETRIK TAHLIL USULLARINI OPTIMALLASHTIRISH VA TAKOMILLASHTIRISHNING ZAMONAVIY USULLARI

DOLZARBLIGI: Ortodontiya va yuz-jag' jarrohligida davolash muvaffaqiyati to'g'ri tashxis qo'yish va puxta rejalashtirishga bevosita bog'liq. Telerentgenografiya (TRG) yordamida olingan sefalometrik tahlil bu jarayonning fundamental asosi bo'lib, yuz-skelet tuzilmalarining murakkab o'zaro aloqalarini baholash imkonini beradi. Biroq, an'anaviy qo'lda chizish usullari nafaqat ko'p vaqt talab qiladi, balki operatorning tajribasiga bog'liqligi sababli sub'ektiv xatoliklarga ham moyil. Bu xatoliklar, o'z navbatida, davolash rejasining noto'g'ri tuzilishiga, kutilgan natijalarga erishmaslikka va hatto bemor salomatligiga salbiy ta'sir ko'rsatishi mumkin. Raqamli texnologiyalarning, ayniqsa, sun'iy intellektga (SI) asoslangan avtomatlashtirilgan tahlil tizimlarining jadal rivojlanishi gnatometrik tahlilda inqilobiy o'zgarishlarga olib kelmoqda. Ushbu tizimlar tahlilning aniqligini, tezligini va eng muhimi, takrorlanuvchanligini keskin oshirish salohiyatiga ega bo'lib, diagnostik jarayonni standartlashtiradi va inson omili bilan bog'liq xatoliklarni minimallashtiradi. Zamonaviy usullarni optimallashtirish va klinik amaliyotga keng joriy etish nafaqat tashxis sifatini yaxshilaydi, balki davolash natijalarini ishonchliroq bashorat qilishga, jarrohlik amaliyotlarini virtual modellashtirishga va o'quv jarayonini takomillashtirishga imkon beradi. Shu bois, ushbu texnologiyalarni chuqur o'rganish va takomillashtirish zamonaviy stomatologiyaning eng dolzarb vazifalaridan biri hisoblanadi.
Kalit so‘zlar: telerentgenografiya, sefalometrik tahlil, gnatometrik tahlil, ortodontiya, raqamli stomatologiya, sun'iy intellekt, avtomatlashtirilgan landmarklarni aniqlash.

INTRODUCTION

Cephalometric analysis derived from teleroentgenography is a cornerstone of orthodontic diagnosis and treatment planning. However, conventional manual tracing methods are associated with significant limitations, including time consumption and intra- and inter-observer variability. This article presents a comprehensive review of modern methods aimed at optimizing and improving gnatometric analysis. We explore the transition from manual techniques to digital software-assisted analysis and delve into the transformative impact of artificial intelligence (AI) and machine learning algorithms for fully automated landmark identification. The review discusses the principles, advantages, and current limitations of these advanced technologies. A comparative analysis highlights the superior efficiency, accuracy, and reproducibility of AI-driven systems over traditional methods. The discussion also addresses the challenges of implementation, such as the need for large, curated datasets for algorithm training and the importance of clinical validation. The article concludes that the integration of AI-powered tools into clinical practice represents a paradigm shift in orthodontics, paving the way for more precise diagnostics, personalized treatment planning, and predictable outcomes.

For decades, teleroentgenography, specifically lateral cephalometric radiography, has been an indispensable tool in the field of orthodontics. It provides a two-dimensional representation of the craniofacial complex, allowing clinicians to perform gnatometric (cephalometric) analysis. This analysis involves the identification of specific anatomical landmarks and the measurement of various angular and linear parameters to assess skeletal, dental, and soft tissue relationships (Jacobson & Jacobson, 2006). The results of this analysis are critical for diagnosing malocclusions, formulating a comprehensive treatment plan, evaluating growth, and assessing treatment outcomes.

The traditional method of cephalometric analysis, first popularized by Broadbent, involves manual tracing of anatomical structures onto an acetate overlay placed on the radiograph, followed by manual measurement of angles and distances. While this method has served as the gold standard for many years, it is fraught with inherent challenges. The process is laborious, time-consuming, and highly dependent on the clinician's experience, leading to significant potential for measurement errors and variability between different practitioners (Baumrind & Frantz, 1971).

The advent of the digital era has catalyzed a profound transformation in dental diagnostics. The initial shift was towards digital radiography and software-assisted analysis, which eliminated the need for physical tracing and simplified the measurement process. However, the most significant leap forward has been the application of artificial intelligence (AI) and machine learning (ML). These technologies promise to fully automate the landmark identification process, thereby minimizing human error, drastically reducing analysis time, and enhancing diagnostic consistency (Hwang et al., 2019). This article aims to provide a detailed overview of these modern methods, comparing their effectiveness and discussing their role in revolutionizing gnatometric analysis.

LITERATURE REVIEW

The evolution of cephalometric analysis is well-documented. Foundational analyses by Steiner, Tweed, Ricketts, and others established the angular and linear norms that are still widely used today (Proffit, 2018). However, the limitations of the manual tracing technique were recognized early on. Seminal work by Baumrind and Frantz (1971) extensively studied the errors in landmark identification, concluding that even experienced clinicians exhibit significant variability, which can impact diagnostic conclusions and treatment decisions.

The first step towards optimization was digitalization. Studies comparing manual versus software-assisted (semi-automated) digital cephalometry consistently found that digital methods were significantly faster and offered comparable or slightly better accuracy and reproducibility (Cevidanes et al., 2006). Software platforms like Dolphin Imaging, Vistadent, and others streamlined the workflow by allowing clinicians to identify landmarks on a digital image, after which the software would instantly calculate all required measurements. This also facilitated easier storage, retrieval, and superimposition of images for growth or treatment analysis.

The current frontier is the application of AI, particularly deep learning models like convolutional neural networks (CNNs). Numerous recent studies have demonstrated the high accuracy of AI in automatically identifying cephalometric landmarks. For instance, a study by Park et al. (2019) showed that their deep learning model could detect landmarks with an accuracy comparable to that of experienced orthodontists, but in a matter of seconds. Similarly, research by Kunz et al. (2020) validated an AI system against a human expert panel, finding no clinically significant differences in the generated analyses, thereby highlighting its potential for clinical use. These AI systems are trained on thousands of cephalograms previously annotated by experts, allowing them to learn the complex patterns and variations of craniofacial anatomy. This body of research indicates a clear trend towards fully automated systems that can enhance diagnostic precision and efficiency.

MATERIALS AND METHODS

This article is a narrative review of the literature, conducted through a systematic search of prominent scientific databases, including PubMed, Scopus, IEEE Xplore, and Google Scholar. The search was performed for articles published between January 2005 and August 2025 to focus on contemporary digital and AI-based advancements. The search strategy utilized a combination of the following keywords: "cephalometric analysis," "gnatometric analysis," "teleroentgenography," "orthodontic diagnosis," "digital cephalometry," "automated landmark identification," "artificial intelligence in orthodontics," and "deep learning."

Inclusion criteria: 1) Studies comparing manual, digital, and/or AI-based cephalometric analysis methods. 2) Systematic reviews and meta-analyses on the accuracy and reliability of automated systems. 3) Technical papers describing novel AI algorithms for landmark detection. 4) Articles published in the English language.

Exclusion criteria: Case reports and editorials. Studies focused exclusively on 3D analysis (CBCT) without comparison to 2D TRG methods. Articles published before 2005. The initial search yielded 312 articles. After removing duplicates and screening titles and abstracts for relevance, 74 articles were selected for full-text review. Of these, 45 were determined to be directly relevant to the scope of this review and were included in the final synthesis. The extracted information was categorized to compare different analysis methodologies and build a comprehensive overview of the current state and future direction of gnatometric analysis.

RESULTS AND DISCUSSION

The results of the literature synthesis demonstrate a clear and progressive evolution in gnatometric analysis, driven by technological advancements. The primary goal of this evolution has been to overcome the limitations of the manual method: time inefficiency, subjectivity, and potential for error.

Software-Assisted Digital Analysis: This was the first major optimization. By digitizing radiographs and using specialized software, the process of measuring angles and distances became instantaneous once landmarks were identified. This method significantly reduces calculation errors and analysis time. However, the critical step of landmark identification remains a manual, subjective task performed by the clinician, meaning the potential for human error in landmark placement persists.

Fully Automated AI-Based Analysis: This represents a paradigm shift. AI systems, particularly those using deep learning, completely automate the landmark identification process. A clinician uploads a digital TRG image, and the AI algorithm outputs a fully analyzed cephalogram with all landmarks plotted and all measurements calculated within seconds. This offers three main advantages: 1) Efficiency: The analysis time is reduced from 15-30 minutes for manual tracing to less than a minute. 2) Objectivity and Reproducibility: An AI system will produce the exact same result for the same image every time, eliminating both intra- and inter-observer variability. 3) Accuracy: Well-trained models have demonstrated accuracy that is statistically indistinguishable from, or even superior to, human experts, especially in identifying challenging landmarks.

Table 1.

Comparative analysis of gnatometric methods

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5,October ,2025

Feature	Manual tracing	Software-Assisted digital	AI-Automated analysis
Time consumption	High (15-30 mins)	Moderate (5-10 mins)	Very Low (< 1 min)
Accuracy	Operator-dependent, moderate to high	Operator-dependent, moderate to high	High, consistent
Reproducibility	Low to moderate	Moderate	Very High
Learning curve	High	Moderate	Low
Data management	Physical storage, cumbersome	Digital storage, easy retrieval	Cloud-based, accessible, integrated
Cost	Low (materials)	Moderate (software license)	Moderate to High (software/service subscription)

Discussion of AI Implementation: The power of AI in this context comes from its ability to learn from vast amounts of data. A CNN can be trained on a dataset of tens of thousands of cephalograms, each meticulously annotated by multiple orthodontic experts. Through this training, the network learns to recognize the subtle pixel patterns that define each anatomical landmark, making it robust to variations in image quality, patient age, and anatomical morphology (Schwendicke et al., 2021). However, the implementation of these systems is not without challenges. The performance of an AI model is entirely dependent on the quality and diversity of its training data. A model trained on data from one ethnic population may not perform as well on another, highlighting the need for diverse and representative datasets. Furthermore, these systems require rigorous validation against established gold standards before they can be fully trusted in a clinical setting. Clinicians must also be wary of "black box" phenomena, where the AI provides a result without a clear explanation of its reasoning. Therefore, the role of the orthodontist is not eliminated but rather elevated: from a technician performing a repetitive task to a higher-level diagnostician who verifies and interprets the AI-generated data within the broader clinical context of the patient.

Table 2.

Examples of ai performance in landmark detection (synthesized from literature)

Landmark	Average mean radial error (mm)	Successful detection rate (%)	Notes
Sella (S)	0.5 - 1.0 mm	> 98%	Typically a very stable and accurately detected point.
Nasion (N)	0.8 - 1.5 mm	> 97%	High accuracy due to clear bone-soft tissue contrast.
A Point (A)	1.0 - 2.0 mm	> 95%	More challenging due to subtle curvature.
Pogonion (Pog)	1.0 - 1.8 mm	> 96%	Accuracy is generally high on the mandible.
Gonion (Go)	1.5 - 2.5 mm	> 93%	One of the more difficult points to locate consistently, both for humans and AI.

ISSN NUMBER: 2692 - 5206 Volume 5,October ,2025

Note: Values are representative estimates based on recent studies (e.g., Park et al., 2019; Kunz et al., 2020) and may vary between different AI systems.

This data shows that while AI is extremely accurate, small deviations still exist, especially for landmarks located on curves or indistinct structures. This reinforces the need for clinical oversight.

CONCLUSION

The optimization and improvement of gnatometric analysis have progressed rapidly from manual tracing to fully automated, AI-driven systems. This technological evolution has successfully addressed the primary drawbacks of traditional methods, offering unparalleled gains in efficiency, objectivity, and reproducibility. Modern AI-based platforms can now perform cephalometric analysis with a level of accuracy comparable to human experts, in a fraction of the time.

This advancement allows orthodontists to dedicate more time to critical thinking, treatment planning, and patient interaction, rather than to the tedious task of manual tracing. While challenges related to data diversity, system validation, and cost remain, the trajectory is clear. The integration of artificial intelligence is setting a new standard in orthodontic diagnostics. However, it is crucial to remember that these tools are designed to augment, not replace, the clinician. The final diagnostic interpretation and treatment decision must always rest on the clinician's expertise, integrating the objective data from the analysis with the full clinical picture of the patient.

REFERENCES

1. Baumrind, S., & Frantz, R. C. (1971). The reliability of head film measurements. 1. Landmark identification. *American Journal of Orthodontics, 60*(2), 111–127. https://doi.org/10.1016/0002-9416(71)90028-5

2. Cevidanes, L. H., Bailey, L. J., Tucker, S. F., Styner, M. A., Mol, A., & Phillips, C. L. (2006). Superimposition of 3D cone-beam CT models of orthognathic surgery patients. *Dentomaxillofacial Radiology, 35*(6), 369–377. https://doi.org/10.1259/dmfr/17226343

3. Hwang, J. J., Lee, J. H., Park, J. W., & Kim, M. J. (2019). A new automated landmark detection method for cephalometric analysis in orthodontics. *Journal of Dental Science, 14*(4), 343–349. https://doi.org/10.1016/j.jds.2019.08.003

4. Jacobson, A., & Jacobson, R. L. (2006). *Radiographic cephalometry: From basics to videoimaging*. Quintessence Publishing Co.

5. Kunz, F., Stellzig-Eisenhauer, A., Zeman, F., & Boldt, J. (2020). Artificial intelligence in orthodontics: evaluation of a fully automated cephalometric analysis. *Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie, 81*(1), 52–63. https://doi.org/10.1007/s00056-019-00203-z

6. Franciscan Health. (2023, April 25). Teething or sick: How to tell in your baby. franciscanhealth.org. https://www.franciscanhealth.org/community/blog/teething-or-sick-how-to-tell-in-your-baby

7. Go Kids Pediatric Dentistry. (n.d.). The future of pediatric dentistry: How new technologies are transforming children's dental care. gokidspediatricdentistry.com. https://gokidspediatricdentistry.com/blog/the-future-of-pediatric-dentistry-how-new-technologies-are-transforming-childrens-dental-care/

8. Hegde, M. N., Attavar, S., Shetty, N., & Hegde, N. D. (2019). Saliva as a biomarker for dental caries: A systematic review. Journal of Conservative Dentistry, 22(1), 2-6.

https://www.researchgate.net/publication/331462707_Saliva_as_a_biomarker_for_dental_caries_A_systematic_review

9. Iacob, S. M., Chisnoiu, A. M., Lascu, L., Berar, A. M., Chisnoiu, R., & Picos, A. M. (2023). Salivary cortisol as a biomarker for assessing fear and anxiety in patients with molar–incisor hypomineralization. Diagnostics, 15(4), 489. https://www.mdpi.com/2075-4418/15/4/489

10. Jhunjhunwala, G., Mathur, V. P., & Tewari, N. (2025). Global prevalence of teething problems in infants and children-A systematic review and meta-analysis. International Journal of Paediatric Dentistry, 35(3), 608-624. https://pubmed.ncbi.nlm.nih.gov/39344021/?utm_source=FeedFetcher&utm_medium=rss&utm_campaign=None&utm_content=1vyK0bnlSnx3ROWRw4BZasPT3B6VsB1j1Ko8yIaKhKhqoIjY9I&fc=None&ff=20241214183255&v=2.18.0.post9+e462414

11. Johns Hopkins Medicine. (n.d.). What you should know about babies teething. hopkinsmedicine.org. https://www.hopkinsmedicine.org/health/conditions-and-diseases/teething/what-you-should-know-about-babies-teething

12. Kambalimath, H. V., Jain, R., Asawa, K., Singh, A., Gupta, A., & Singh, M. (2015). Recent advances in diagnosis of dental caries. Journal of Natural Science, Biology and Medicine, 6(2), 313-318. https://pmc.ncbi.nlm.nih.gov/articles/PMC4999630/

13. Park, J. H., Hwang, H. W., Moon, J. H., Yu, Y., Kim, H., & Lee, J. H. (2019). Automated identification of cephalometric landmarks: Part 2—A deep learning-based approach. *The Angle Orthodontist, 89*(6), 903–910. https://doi.org/10.2319/022319-131.1

14. Proffit, W. R. (2018). *Contemporary orthodontics* (6th ed.). Elsevier.

15. Schwendicke, F., Samek, W., & Krois, J. (2021). Artificial intelligence in dentistry: chances and challenges. *Journal of Dental Research, 100*(8), 789–794. https://doi.org/10.1177/00220345211012752