RESEARCH ARTICLE

Accuracy and Reliability of Artificial Intelligence-Based and App-Based Cephalometric Analysis Compared with Conventional Manual Tracing: An In Vitro Comparative Study

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ABSTRACT
Thirty pretreatment lateral cephalograms were analyzed using manual tracing, CEPHIO, and WEBCEPH. A total 30 cephalometric analysis Nine angular and five linear parameters were evaluated
Background: Cephalometric analysis is fundamental to orthodontic diagnosis and treatment planning. AI-based and app-based cephalometric software have been developed to reduce the time and operator variability associated with conventional manual tracing.
Aim: To evaluate and compare the accuracy and reliability of CEPHIO, WEBCEPH, and conventional manual tracing.
Materials and Methods: Thirty pretreatment lateral cephalograph were analyzed using manual tracing, CEPHIO, and WEBCEPH. A total 30 cephalometric analysis Nine angular and five linear parameters were evaluated. Manual tracing served as the reference standard.
Results: WEBCEPH showed closer agreement with manual tracing for most parameters, while CEPHIO demonstrated greater deviations, particularly for skeletal linear measurements.
Conclusion: WEBCEPH demonstrated superior accuracy and reliability compared with CEPHIO; however, manual tracing remains the reference standard for complex landmark identification.
Keywords: Artificial intelligence; Cephalometric analysis; WEBCEPH; CEPHIO; Manual tracing; Orthodontics.
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INTRODUCTION

Cephalometric is a compound Latin word that includes two distinct terms: cephalo (the head), and metrics (measurements). Thus, cephalometry is the art of the human head measurements which is used to evaluate craniofacial growth [1]. Cephalometric radiography is an important diagnostic method that determines the morphology, development, and diagnosis in dental or skeletal abnormalities [1,2].

It is also helpful in evaluating the changes cephalometric radiographs to investigate growth and development of the facial skeleton can assist in treatment planning, and changes between pre- and post-treatment measurements can help in treatment evaluation (Brodie, 1941; Baumrind and Frantz, 1971a, b; Ricketts, 1981) [3,4].

Cephalometry has been instrumental in orthodontic diagnosis, treatment planning, and craniofacial growth prediction. Manual tracing of lateral cephalograms has been in practice for many years. Angular and linear measurements on the lateral cephalogram are carried out with an acetate tracing paper, scale, and protractor [4]. Even though this method is considered to be the gold standard, it is a time-consuming and labor-intensive method that requires experience and skill, and it is also affected by factors such as the quality of the radiographs and human-related issues like fatigue, which has led researchers [5]. Around 350 specially designed orthodontic applications exist as of today indicating the boom in software development and technology [6]. Artificial intelligence (AI) is the ability of a machine to imitate logical human

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behaviour, including complex activities[1,7]. For the first time, this term was introduced by John McCarthy during a conference at Dartmouth College in 1956[2,8].

Artificial intelligence is used on a daily basis in the internet search engines (Google) and online private intelligent assistants (Siri), also rapidly evolving in other areas, including medicine [9-11]. AI algorithms can be useful in the diagnosis of dental caries, periapical or periodontal diseases, classification of maxillofacial cysts or tumours and localisation of cephalometric landmarks [11,12].

Thus, the present study was designed to evaluate and compare the accuracy and reliability of three different cephalometric programs: Web site based Artificial intelligence system CEPHIO, App-based system WEBCEPH and Conventional Hand tracing method.

MATERIALS AND METHODS

All the procedures of the study were in accordance with the Declaration of College,and this retrospective study received approval from the Ethics Committee of MUHS Nashik University (date: 6 october 2026)

The cephalostat used was Genoray provided by Genoray Papaya 3D plus.

Table 1. Angular and Linear measurement

ANGULAR MEASUREMENTS		
1.	SNA	Anteroposterior position of the maxilla relative to the anterior cranial base
2.	SNB	Anteroposterior position of the mandible relative to the anterior cranial base
3.	ANB	The difference between SNA and SNB angles and defines the mutual
4.	SN – MP	The angle formed between the SN plane and the mandibular plane
5.	SN – PP	The angle formed between the SN plane and the palatal plane
6.	PP – MP	The angle formed between the palatal plane and the mandibular plane
7.	Gonial Angle	The angle between mandibular plane and ramal plane
8.	Upper Incisor to SN	The angle formed between the long axis of upper central incisor and the anterior cranial base
9.	Lower incisor to mandibular plane	The angle formed between long axis of lower central incisor and the mandibular plane
LINEAR MEASUREMENTS		
1.	Anterior Cranial Base (N – S)	The linear distance from sella turcica and anterior point of the frontonasal suture
2.	Mandibular Body Length (Go – Gn)	Linear distance from gonion and gnathion
3.	LAFH	The lower anterior facial height, linear distance from ANS to menton
4.	Upper incisor to NA	Linear measurement forms the labial aspect of upper incisor to NA
5.	Lower incisor to NB	Linear measurement forms the labial aspect of lower incisor to NB

Table 2. Descriptive Statistics of Angular Measurements & Linear Measurements (°)- Table summarizes the mean values for the 9 angular parameters derived from the master data of 30 samples

9 ANGULAR MEASUREMENTS			
Parameter	Manual Hand Tracing (Mean ± SD)	WEBCEPH (Mean ± SD)	CEPHIO (Mean ± SD)
SNA	86.27 +/- 5.86	86.21 +/- 4.40	83.99 +/- 4.98
SNB	80.67 +/- 5.82	79.87 +/- 4.91	79.41 +/- 4.97
ANB	5.73 +/- 3.50	6.37 +/- 3.41	4.91 +/- 3.10
Go-Gn to SN	25.10 +/- 7.10	24.41 +/- 6.90	26.91 +/- 7.20
SN-PP Angle	6.50 +/- 2.10	5.90 +/- 2.30	6.64 +/- 2.00
PP-MP	19.20 +/- 5.40	19.16 +/- 5.10	20.10 +/- 5.60
Gonial Angle	120.00 +/- 7.73	115.20 +/- 9.30	118.96 +/- 7.07
U1 to SN Angle	114.00 +/- 10.85	110.24 +/- 9.85	109.38 +/- 9.05
L1 to Mand. Plane	105.10 +/- 8.20	105.51 +/- 7.90	106.31 +/- 8.10
5 LINEAR MEASUREMENTS			
Parameter	Manual Hand Tracing (Mean ± SD)	WEBCEPH (Mean ± SD)	CEPHIO (Mean ± SD)
Anterior Cranial (N-S)	60.83 mm	68.65 mm	71.50 mm
Mandibular Body Length	61.13 mm	70.00 mm	77.28 mm
Lower Ant. Facial Height (LAFH)	54.90 mm	64.57 mm	61.35 mm
U1 to NA	4.97 mm	4.80 mm	4.54 mm
Anterior Cranial (N-S)	60.83 mm	68.65 mm	71.50 mm

A total of the same 30 subject groups was analyzed into three different cephalometric programs.

Group A: Tracing performed using Web site-based A.I system CEPHIO. (30)

Group B: Tracing performed using App-based system WEBCEPH. (30)

Group C: Tracing performed using Conventional Hand tracing method. (30)

The Cephalometric Analysis Methods Used in the Study (Fig.1)

Manual Method

Translucent acetate paper (0.003 inches thick, 8″ × 10″ inches in size) specifically designed for orthodontic analysis was fixed to radiographic printouts. They were placed on a negatoscope in a darkened drawing room, and the anatomical points used in the present study were carefully marked using a Rotring drawing pen (0.3 mm) for both hard and soft tissue drawings. Angular and linear measurements were performed by the same authors using a protractor.

Computerized Digital Tracing

All the images were directly imported to the Website based Artificial intelligence system and App. based system. The images were calibrated by using the ruler built in within the cephalostat. This was done with a website-based A.I system and App. based system, digital images were imported to the website based and App based system, the cephalometric landmarks were located using Artificial intelligence and cross-hair tools available with each softwares, with the help of the mouse. During the process of identification of the landmarks digital image enhancing functions like magnification, brightness and contrast were used. Once the landmarks were marked the digital site analysed the tracing and the values for 9 angular and 5 linear measurements were generated. This was done with two digital systems namely WEBCEPH and CEPHIO(Fig.1), (Table 1& 2).

RESULTS

Thirty pretreatments lateral cephalograph were analyzed using manual tracing, CEPHIO, and WEBCEPH. A total 30 cephalographs obtain between the age of 18 to 35 years out of which 16 males and 14 female's samples were taken. From which Nine angular and five linear parameters were evaluated across three different cephalometric programs.

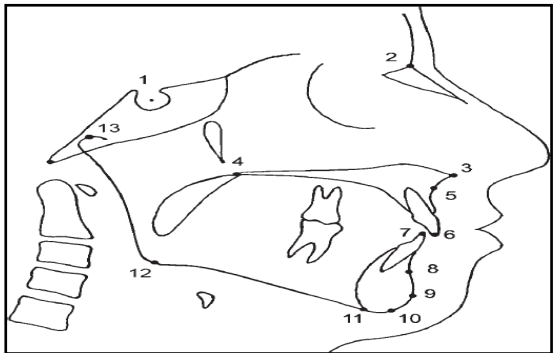
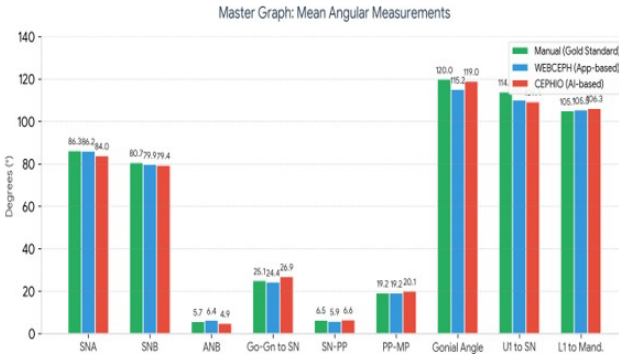
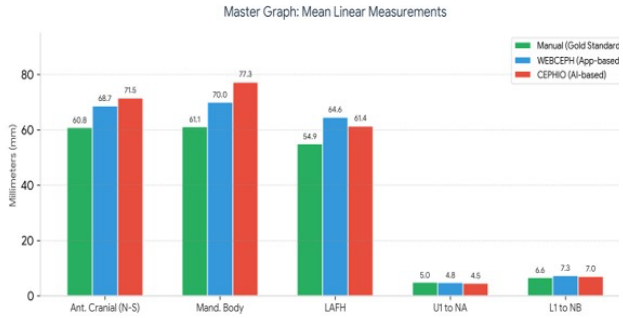


Figure 1. Cephalometric landmarks used in this study, 1 – Sella (S), 2 – Nasion (N), 3 – Anterior nasal spine (ANS), 4 – Posterior nasal spine (PNS), 5– Point A, 6 – Incisor superius (Is), 7 – Incisor inferius (Ii), 8 – Point B, 9 –Pogonion (Pg), 10 – Gnathion (Gn), 11 – Menton (Me), 12 – Gonion (Go), 13 – Condylion (Co), 14 – Articulare (Ar), 15 – Porion (po), 16 – Orbitale (Or), 17 – Upper incisor axis (UI), 18 – Lower incisor axis



Graph 1. Comparison of Mean Angular Measurement across the three study groups



Graph 2. Comparison of Mean Linear Measurement across the three study group

Skeletal Base Relationships (SNA, SNB, ANB): SNA (Maxillary Position): WEBCEPH demonstrated exceptionally high agreement with manual tracing (86.21 vs. 86.27) as shown in Graph 1. Vertical Skeletal Inclinations (Go-Gn to SN, SN-PP, PP-MP): Go-Gn to SN: For this vertical parameter, WEBCEPH (24.41) was more consistent with the gold standard (25.10) than CEPHIO, which recorded a higher mean of 26.91. Dental Inclinations and Mandibular Morphology: Gonial Angle: Manual tracing recorded a mean of 120.00. CEPHIO (118.96) was closer to the reference than WEBCEPH (115.20). Skeletal Accuracy (N-S & Mandibular Body): Significant differences were observed in skeletal length measurements, with digital systems generally demonstrating a tendency to overestimate these values as shown in Graph 2. Vertical Linear Dimension (LAFH): While all methods showed variance, the Manual Hand Tracing reference (54.90 mm) was consistently lower than the values recorded by the automated systems. Dental Linear Parameters (U1 to NA, L1 to NB): WEBCEPH (4.80 mm) showed the closest correlation to the Manual gold standard (4.97 mm)

DISCUSSION

This study evaluated the diagnostic precision of two digital cephalometric tools—WEBCEPH (an app-based software) and CEPHIO (an AI-driven web platform)—against the traditional gold standard of manual tracing. Using 30 lateral cephalograms, we found that WEBCEPH consistently

produced measurements much closer to manual tracing than CEPHIO.

For key skeletal indicators (SNA, SNB, and ANB), WEBCEPH showed negligible deviation from manual records. CEPHIO, however, frequently underestimated maxillary position and miscalculated sagittal discrepancies, pointing to flaws in its automated landmark detection[13-14]. WEBCEPH also matched manual vertical growth assessments (PP-MP angle) nearly perfectly. Although all three methods showed strong agreement in dental linear parameters, the digital systems—especially CEPHIO—overestimated skeletal lengths like the mandibular body, likely due to scaling and magnification errors. Statistical evaluations, including Mean Absolute Error (MAE) and Pearson's correlation, confirmed WEBCEPH's higher reliability[15,16,17].

Our results mirror recent findings in the literature. Studies by Gupta S. et al.and Prince STT et al. noted that fully automated AI platforms still struggle with precise landmark identification compared to app-based or manual methods[5,17]. Likewise, Pragya P. et al. also supported the general clinical reliability of digital cephalometric software[19]. Senol Koz et al. and Katyal D. et al. confirm that tools like WebCeph drastically reduce analysis time while maintaining high accuracy[12,20].

Cephalometric programs using AI are rapidly becoming popular as one of the most important criteria and source of error in cephalometrics in landmark identification. AI allows landmarks to be detected automatically instead of manually having to locate landmarks thus reducing the probability of error[20].

CONCLUSION

WEBCEPH and CEPHIO demonstrated lower mean absolute error values and stronger Pearson's correlation coefficients with manual tracing, indicating superior reproducibility and diagnostic consistency.

Conventional manual tracing still remains the gold standard because of its superior precision in identifying complex anatomical landmarks. Nevertheless, digital cephalometric systems significantly improve efficiency, reduce analysis time, and enhance workflow in orthodontic practice.

Therefore, WEBCEPH can be considered a clinically reliable and practical alternative to conventional hand tracing for routine cephalometric analysis, while CEPHIO may serve as a supportive adjunct tool pending further technological improvements

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