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Comparison of contemporary cephalometric methods for different malocclusions

Farklı maloklüzyon tipleri için güncel sefalometrik yöntemlerin karşılaştırılması

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Abstract

Aim: This study aimed to evaluate the reliability of two widely used web-based cephalometric analysis programs, WebCeph and Nemoceph, in comparison with the conventional manual method.

Materials and Methods: A total of 150 lateral cephalometric radiographs from patients with Class I, II, and III malocclusions were analyzed. Eighteen cephalometric parameters were measured by two researchers using manual, WebCeph, and Nemoceph methods. Intra- and inter-method reliability was assessed using Intragroup Correlation Coefficient (ICC), paired t-tests, ANOVA, and post-hoc analyses.

Results: High correlation was observed among the three methods for skeletal and dental measurements. However, soft tissue measurements showed lower consistency across methods.

Conclusion: There were no clinically significant differences between manual and digital methods. WebCeph and Nemoceph provide reliable alternatives to traditional cephalometric analysis and offer notable advantages in terms of time and clinical efficiency.

Keywords: Cephalometry, Digital analysis, WebCeph, Nemoceph.

Öz

Amaç: Bu çalışma, ortodontik tanıda yaygın olarak kullanılan iki web tabanlı sefalometrik analiz programı olan WebCeph ve Nemoceph'in güvenilirliğini geleneksel manuel yöntemle karşılaştırmayı amaçlamaktadır.

Gereç ve Yöntem: Sınıf I, II ve III maloklüzyona sahip 150 hastaya ait lateral sefalometrik radyografiler analiz edilmiştir. On sekiz sefalometrik parametre, iki araştırmacı tarafından manuel, WebCeph ve Nemoceph yöntemleri kullanılarak ölçülmüştür. Yöntemler arası ve araştırmacılar arası güvenilirlik İntra Grup Korelasyon Katsayısı (ICC), eşleştirilmiş t-testi, ANOVA ve post-hoc testlerle değerlendirilmiştir.

Bulgular: İskeletsel ve dentoalveolar ölçümler arasında üç yöntem arasında yüksek düzeyde korelasyon gözlenmiştir. Ancak, yumuşak doku ölçümlerinde yöntemler arasında daha düşük tutarlılık bulunmuştur.

Sonuç: Manuel ve dijital yöntemler arasında klinik olarak anlamlı bir fark bulunmamıştır. WebCeph ve Nemoceph, geleneksel sefalometrik analizlere güvenilir bir alternatif sunmakta ve klinik uygulamalarda zaman ve verimlilik açısından önemli avantajlar sağlamaktadır.

Anahtar Kelimeler: Sefalometri, Dijital analiz, WebCeph, Nemoceph.

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Bu makale araştırma ve yayın etiğine uygun hazırlanmıştır.
intihal incelemesinden geçirilmiştir.

Introduction

Cephalometric analysis is considered a fundamental clinical tool for orthodontic diagnosis, treatment planning, monitoring growth and development, and evaluating treatment outcomes.[1] In addition, cephalometric measurements enable an objective assessment of the relationships between craniofacial structures and allow the three-dimensional growth patterns of skeletal, dentoalveolar, and soft-tissue components to be analyzed through two-dimensional projections, making cephalometry an indispensable component of orthodontic decision-making.[2,3] Cephalometry plays a critical role in numerous orthodontic applications, including the identification of skeletal discrepancies, evaluation of sagittal and vertical relationships, treatment mechanics planning, and growth assessment.[4] However, conventional cephalometric techniques also present notable diagnostic limitations, such as measurement errors, superimposition challenges, and the inherent constraints of two-dimensional imaging.[2] Owing to these strengths and limitations, cephalometric analysis remains one of the most essential diagnostic tools in both clinical and academic orthodontics.[4] Advances in technology have enabled the development of digital cephalometric analysis software to address these disadvantages of the conventional method. These computer-aided systems have quickly gained widespread acceptance, offering advantages such as accelerating the analysis process, facilitating archiving and data sharing, and enhancing measurement precision. Additionally, it incorporates different analysis protocols and offers the user the opportunity to perform detailed measurements of both hard and soft tissues.[5,6] However, a significant portion of existing digital systems operate on a semi-automatic principle. Because the identification and marking of anatomical landmarks in these systems are also performed manually by the clinician, operator-related variability, a primary source of error in cephalometric analysis, can be encountered.[7]

To overcome this fundamental limitation and further optimize the analysis process, fully automated artificial intelligence (AI)-based cephalometric analysis programs have been developed in recent years. These programs promise to minimize subjective errors and significantly shorten analysis time by detecting anatomical landmarks without human intervention.[8,9,10] However, the novelty of these technologies, the existence of conflicting findings in the literature comparing manual and digital methods,[11,12,13] and the limited clinical validity of fully automated systems necessitate a comprehensive evaluation of the reliability of these new-generation software.[6,14]

In this context, this study aimed to compare traditional manual cephalometric analysis with Nemoceph (Nemotech, Madrid, Spain), a computer-aided software with proven validity in the literature,[15] and WebCeph, an AI-based fully automated platform, in terms of reliability, reproducibility, and accuracy on cephalometric radiographs of different malocclusions. The null hypothesis of the study was that there was no statistically significant difference in accuracy in cephalometric measurements for different malocclusions among the three methods examined. The study findings are intended to provide clinicians with evidence-based data regarding the role and accuracy of fully automated cephalometric analysis systems in clinical practice.

Materials and Methods

Type of the study

This study was designed according to the retrospective, cross-sectional, comparative and quantitative research model.

The sample size of the study

A Power Analysis was performed for the sample size in the study, and it was determined that at 90% power, a minimum of 28 individuals for each subgroup of malocclusion types, for a total of 84 individuals, was sufficient. To increase the power of the study, more individuals were included. The study sample consisted of 150 individuals selected from among patients who presented to the clinic for malocclusion treatment and requested lateral cephalometric radiographs

for orthodontic diagnosis. The sample was divided into three groups, 50 individuals in each, according to the Steiner analysis: Group 1 (n=50): Class I malocclusion, Group 2 (n=50): Class II malocclusion, and Group 3 (n=50): Class III malocclusion. Radiographs of individuals with a history of cleft lip or palate or any known syndromic deformity, and those with significant craniofacial anomalies or asymmetry were excluded from the study.

In this study, all lateral cephalometric radiographs were obtained under standardized conditions by the same technician using a Planmeca ProMax 2D device (Planmeca OY, Asentajankatu 6, 00880 Helsinki, Finland) with exposure parameters of 66 kVp and 10 mA for 6.7 seconds.

To ensure standardization of the lateral cephalometric radiographs, the ear rods of the same cephalostat were bilaterally positioned in the patients' external auditory meatuses. During image acquisition, the Frankfurt horizontal plane was adjusted to be parallel to the ground and the patients were positioned in their natural head posture. The lips were relaxed, and the patients were instructed to occlude their posterior teeth in maximum intercuspation (centric occlusion) during imaging.

Data collection tools

Each radiograph was analyzed by two different researchers using manual, digital, and AI-based automated methods. To ensure inter- and intra-observer consistency, measurements by each researcher were repeated two weeks apart. The intra-class correlation coefficient for the first and second measurements was 0.964 (0.944–0.982), indicating excellent agreement between the two measurements by the same researcher. Additionally, the inter-class correlation coefficient was 0.939 (0.917–0.961), demonstrating excellent agreement between the two researchers. These high correlation values indicate excellent agreement between the measurements, and no statistically significant difference was observed between the measurements.

Analyses were performed on cephalometric radiographs in "jpeg" format with a resolution of 2285x2216 pixels, 150 dpi sensitivity, and 24-bit color depth. After the images were imported into the Nemoceph program, they were calibrated using the software's ruler. Anatomical landmarks were identified manually by the researcher, and measurements were calculated by the software. AI-based automated analyses were performed using the WebCeph (WebCeph™, Seoul, South Korea) platform. In this process, lateral cephalometric radiographs in JPEG format were uploaded to the program under anonymized filenames and calibrated. Then, by selecting the "AI based" tab, the software automatically identified the anatomical landmarks. The identified points were saved by clicking the "Save" option. Subsequently, the "Analysis" tab was opened to access the list of analyses, and the values of the parameters used in this study were transferred to a table prepared in Microsoft Excel. The results were verified for accuracy by both researchers.

For the application of the manual analysis method, film prints were obtained using a radiographic printer at a 1:1 magnification ratio. Transparent acetate sheets specially manufactured for orthodontic analysis (0.003-inch thick, 8″×10″ in size; GAC International Inc., Bohemia, NY, USA) were affixed onto the printed films using transparent tape.

Subsequently, the films were placed on a negatoscope in a dark tracing room, and both hard and soft tissue outlines were drawn using a 0.3 mm Rotring technical pencil. Anatomical landmarks to be used in the study were carefully marked on these tracings. The marked points were then connected with the aid of a protractor to construct the reference lines required for the analysis. Angular and linear measurements were also obtained using the protractor.

Six skeletal (SNA (The angle formed between the Sella–Nasion line and the Nasion–A point line), SNB (The angle formed between the Sella–Nasion line and the Nasion–B point line), ANB (the angle between NA and NB lines indicating the sagittal relationship between the maxilla and mandible), Wits (the linear distance between the perpendicular projections of Points A and B on the occlusal plane, indicating the sagittal jaw relationship), Gonial Angle (The angle formed between the

Articulare, Gonion, and Menton points), SN-Go/Gn (The angle formed between the Sella–Nasion line and the Gonion–Gnathion line)), nine dentoalveolar (Overjet (the horizontal distance between the incisal edge of the maxillary central incisor and the labial surface of the mandibular central incisor), overbite (the vertical overlap between the incisal edges of the maxillary and mandibular central incisors), U1-SN (the angle between the long axis of the upper central incisor and the Sella–Nasion line, indicating the inclination of the upper incisor to the cranial base), U1-FH (the angle between the long axis of the upper central incisor and the Frankfurt horizontal plane, indicating the inclination of the upper incisor to the horizontal plane), U1-NA (The angle between the long axis of the upper central incisor and the N–A line), IMPA (the angle between the long axis of the lower central incisor and the mandibular plane, indicating the inclination of the lower incisor), L1-NB (The angle between the long axis of the lower central incisor and the N–B line)), and three soft tissue (E Line (the line drawn from the tip of the nose to the soft tissue pogonion, used to assess the anteroposterior position of the lips), S Line (the line drawn from the tip of the nose to the soft tissue pogonion, used to evaluate the aesthetic position of the lips relative to the face), Nasolabial Angle (the angle formed between the Pronasale, Subnasale, and Labium Superius points)) measurements frequently used in clinical practice were used for each patient in the analyses.

Data Analysis

The data were analyzed using the SPSS software (version 22.0 for Windows). Descriptive statistics, such as the mean and standard deviation, were computed. To assess the relationships between cephalometric measurements obtained through manual, digital, and AI-based methods across the three malocclusion groups, correlation tests were applied. Intra-correlation coefficients and corresponding significance values were recorded, with statistical significance defined as $p<0.05$.

Ethics committee approval

Ethics Committee approval was obtained from the Ankara Medipol University Institute Research Ethics Committee (decision number : 172 date 16.09.2025).

Results

Three cephalometric techniques—manual, digital, and artificial intelligence-based—were evaluated across Class I, Class II, and Class III malocclusion groups (Figure 1).

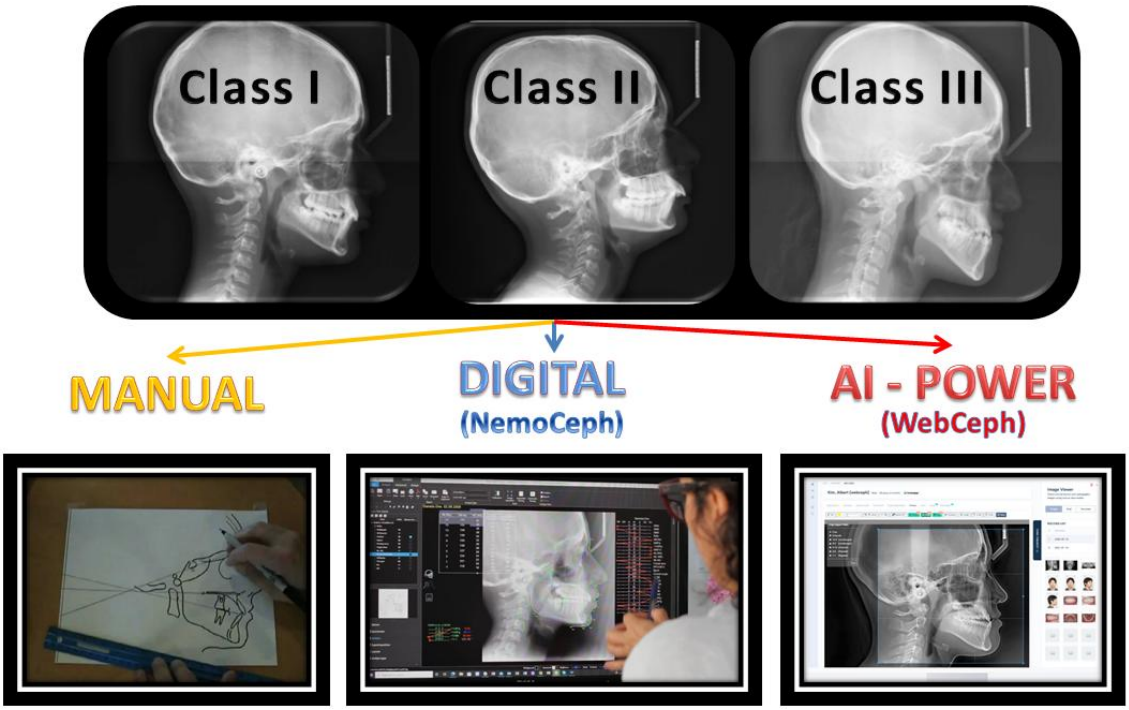


Figure 1. Lateral cephalometric radiographs of Class I, II, and III malocclusion groups analyzed using manual, digital, and AI-based methods.

Findings for Class I Malocclusion (Table 1):

Table 1. Comparison of cephalometric measurements of individuals with Class I malocclusion made with three different methods.

		NORM	GROUP 1 (MANUAL)	GROUP 2 (DIGITAL)	GROUP 3 (AI – BASED)	ICC			*p*		
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	1 - 2	1 - 3	2 - 3	1 - 2	1 - 3	2 - 3
SKELETAL	SNA (°)	82° ± 2°	81.79 ± 3.4	81.44 ± 3.19	82.63 ± 3.74	.902	.900	.898	***	***	***
	SNB (°)	80° ± 2°	78.88 ± 2.89	78.66 ± 3.87	79.09 ± 3.19	.830	.938	.828	***	***	***
	ANB (°)	2° ± 2°	2.89 ± 0.26	2.52 ± 0.32	3.54 ± 0.31	.507	.681	.736	**	***	***
	Wits (mm)	0 mm ± 2	0.52 ± 0.41	-0.56 ± 0.63	0.14 ± 0.58	.780	.885	.797	***	***	***
	Gonial Angle (°)	120° ± 5°	120.45 ± 0.86	124.33 ± 2.09	121.03 ± 0.85	.567	.759	.233	**	***	NS
	SN-Go/Gn (°)	32° ± 6°	30.55 ± 0.46	30.25 ± 0.42	29.89 ± 0.27	.931	.952	.909	***	***	***
DENTOALVEOLAR	Overjet (mm)	2–3 mm	3.58 ± 0.41	3.34 ± 0.44	3.81 ± 0.43	.911	.933	.890	***	***	***
	Overbite (mm)	2–3 mm	1.42 ± 0.35	0.97 ± 0.43	1.33 ± 0.37	.762	.926	.844	***	***	***
	U1-FH (°)	111° ± 5°	111.61 ± 1.23	112.38 ± 1.11	113.14 ± 1.09	.620	.915	.722	***	***	***
	U1-SN (°)	102° ± 2°	104.64 ± 1.26	105.5 ± 1.06	105.91 ± 1.13	.667	.882	.721	***	***	***
	U1-NA (°)	22° ± 4°	22.67 ± 1.06	24.54 ± 1.13	23.67 ± 1.26	.710	.848	.747	***	***	***
	U1-NA (mm)	4 mm ± 1 mm	3.48 ± 0.37	4.14 ± 0.41	3.35 ± 0.37	.779	.895	.755	***	***	***
	IMPA (°)	90° ± 5°	91.36 ± 1.03	92.47 ± 1.18	91.95 ± 1.14	.720	.900	.805	***	***	***
	L1-NB (°)	25° ± 4°	23.76 ± 0.81	24.34 ± 1.3	23.48 ± 1.05	.744	.855	.823	***	***	***
	L1-NB (mm)	4 mm ± 1 mm	4.18 ± 0.29	3.79 ± 0.31	4.38 ± 0.28	.755	.844	.867	***	***	***
SOFT TISSUE	E Line (mm)	–4 ± 2 mm	-2.5 ± 0.36	-2.12 ± 0.6	-2.85 ± 0.39	.321	.950	.311	NS	***	NS
	S Line (mm)	0±1 mm	-1.63 ± 0.47	-1.39 ± 0.69	-1.63 ± 0.40	.316	.885	.304	NS	***	NS
	Nasolabial Angle (°)	102°–110°	96.15 ± 2.26	92.27 ± 2.68	96.34 ± 2.54	.632	.979	.617	***	***	***

SD Standard Deviation; NS: Not significant; *P*: Results of ICC; * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Skeletal Measurements: Statistically strong correlations were observed among the three methods for SNA, SNB, Wits appraisal, and SN-GoGn angles ($p<0.001$). ANB angle also showed a significant correlation between all three methods ($p<0.01$–0.001). The Gonial angle did not show a statistically meaningful relationship between digital and AI-based analyses ($p>0.05$).

Dental Measurements: For dental variables—such as overjet, overbite, and incisor inclinations and positions (e.g., U1-FH, U1-SN, U1-NA, L1-NB, IMPA)—a strong correlation was evident among all three techniques ($p<0.001$).

Soft Tissue Measurements: Although the S Line and E Line values did not show a statistically significant correlation between manual and digital methods ($p>0.05$), the nasolabial angle measurements were highly correlated across all techniques ($p<0.001$).

Findings for Class II Malocclusion (Table 2):

Skeletal Measurements: There were highly significant correlations among the three methods for the SNA, SNB, Wits, and SN-GoGn values ($p<0.001$). The ANB and Gonial angle showed a significant, but slightly lower correlation compared to other skeletal parameters between Groups 1-2 (manual-digital) ($p<0.01$).

Table 2. Comparison of cephalometric measurements of individuals with Class II malocclusion made with three different methods.

		NORM	GROUP 1 (MANUAL)	GROUP 2 (DIGITAL)	GROUP 3 (AI – BASED)	ICC			*p*		
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	1 - 2	1 - 3	2 - 3	1 - 2	1 - 3	2 - 3
SKELETAL	SNA (°)	82° ± 2°	83.15 ± 4.28	83.58 ± 4.69	83.62 ± 4.3	.892	.959	.934	***	***	***
	SNB (°)	80° ± 2°	76.79 ± 4.22	75.96 ± 4.49	76.34 ± 4.46	.895	.963	.904	***	***	***
	ANB (°)	2° ± 2°	6.36 ± 2.24	7.61 ± 2.46	7.19 ± 2.2	.471	.776	.593	**	***	***
	Wits (mm)	0 mm ± 2	4.12 ± 1.74	4.19 ± 2.31	4.19 ± 2.7	.602	.653	.974	***	***	***
	Gonial Angle (°)	120° ± 5°	120.69 ± 5.24	121.79 ± 6.04	122.02 ± 5.47	.843	.890	.941	**	***	***
	SN-Go/Gn (°)	32° ± 6°	29.13 ± 1.92	29.68 ± 2.04	29.87 ± 1.28	.898	.813	.834	***	***	***
DENTOALVEOLAR	Overjet (mm)	2–3 mm	5.7 ± 2.26	5.94 ± 2.21	6.1 ± 2.53	.882	.865	.964	***	***	***
	Overbite (mm)	2–3 mm	2.82 ± 1.7	2.73 ± 1.68	2.72 ± 1.94	.931	.929	.965	***	***	***
	U1-FH (°)	111° ± 5°	108.15 ± 8.41	110.63 ± 8.45	110.35 ± 8.56	.778	.844	.953	***	***	***
	U1-SN (°)	102° ± 2°	101.39 ± 8.53	101.82 ± 9.11	102.33 ± 8.69	.902	.919	.965	***	***	***
	U1-NA (°)	22° ± 4°	18.5 ± 9.28	18.58 ± 9.75	18.77 ± 9.61	.911	.931	.939	***	***	***
	U1-NA (mm)	4 mm ± 1 mm	3.16 ± 1.67	3.41 ± 1.76	3.3 ± 1.74	.983	.989	.978	***	***	***
	IMPA (°)	90° ± 5°	96.79 ± 5.99	96.85 ± 5.52	97.24 ± 6.21	.843	.917	.930	***	***	***
	L1-NB (°)	25° ± 4°	26.77 ± 5.66	27.24 ± 5.98	27.74 ± 5.8	.890	.893	.915	***	***	***
	L1-NB (mm)	4 mm ± 1 mm	5.34 ± 2.42	5.62 ± 2.55	5.77 ± 2.67	.917	.888	.965	***	***	***
SOFT TISSUE	E Line (mm)	–4 ± 2 mm	0.42 ± 2.78	0.38 ± 2.68	0.33 ± 2.67	.945	.958	.946	***	***	***
	S Line (mm)	0±1 mm	0.72 ± 2.48	0.75 ± 2.56	0.83 ± 2.84	.968	.970	.960	***	***	***
	Nasolabial Angle (°)	102°–110°	100.88 ± 12.63	99.96 ± 13.57	101.63 ± 13.62	.950	.965	.935	***	***	***

SD Standard Deviation; NS: Not significant; *P*: Results of ICC; * *P*<.05, ** *P*<.01, *** *P*<.001

Skeletal Measurements: There were highly significant correlations among the three methods for the SNA, SNB, Wits, and SN-GoGn values (p<0.001). The ANB and Gonial angle showed a significant, but slightly lower correlation compared to other skeletal parameters between Groups 1-2 (manual-digital) (p<0.01).

Dental and Soft Tissue Measurements: Consistent and statistically significant agreements (p<0.001) were identified between all methods for measurements such as overjet, overbite, upper and lower incisor positioning, as well as for soft tissue indicators like the E Line, S Line, and nasolabial angle.

The analysis results for Class III malocclusion are presented in Table 3;

Skeletal Measurements: Highly significant and positive correlations were found between all methods for the SNA, SNB, and ANB angles (p<0.001). Significant correlations were also found for the Wits value and Gonial angle, while a statistically significant but lower correlation was observed for the SN-Go/Gn angle when comparing the manual method with the digital and artificial intelligence methods (p<0.05).

Dental Measurements: Strong correlations were found between the methods for dental parameters (p<0.001). However, no significant correlation was found between the manual and digital methods for the L1-NB (mm) measurement (p>0.05).

Table 3. Comparison of cephalometric measurements of individuals with Class III malocclusion made with three different methods.

		NORM	GROUP 1 (MANUAL)	GROUP 2 (DIGITAL)	GROUP 3 (AI – BASED)	ICC			*p*		
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	1 - 2	1 - 3	2 - 3	1 - 2	1 - 3	2 - 3
SKELETAL	SNA (°)	82° ± 2°	78.83 ± 2.4	79.81 ± 2.96	79.88 ± 2.98	.702	.679	.966	***	***	***
	SNB (°)	80° ± 2°	79.1 ± 2.82	80.1 ± 2.84	80.38 ± 3.02	.663	.680	.940	***	***	***
	ANB (°)	2° ± 2°	-0.3 ± 1.7	-0.35 ± 1.61	-0.49 ± 1.66	.711	.729	.948	**	**	***
	Wits (mm)	0 mm ± 2	-4.53 ± 1.54	-5.35 ± 2.61	-5.31 ± 2.51	.468	.578	.958	**	**	***
	Gonial Angle (°)	120° ± 5°	126.53 ± 5.16	127.03 ± 4.66	127.47 ± 5.01	.475	.471	.951	**	***	***
	SN-Go/Gn (°)	32° ± 6°	29.31 ± 2.71	30.67 ± 1.57	30.51 ± 1.52	.421	.420	.849	*	*	***
DENTOALVEOLAR	Overjet (mm)	2–3 mm	-0.78 ± 1.55	-0.87 ± 1.74	-0.77 ± 1.7	.571	.558	.962	**	**	***
	Overbite (mm)	2–3 mm	0.83 ± 1.94	1.07 ± 1.69	1.05 ± 1.72	.683	.649	.950	***	***	***
	U1-FH (°)	111° ± 5°	109.77 ± 6.19	111.64 ± 6.69	11.89 ± 6.88	.754	.748	.983	***	***	***
	U1-SN (°)	102° ± 2°	102.03 ± 7.12	104.28 ± 6.5	104.47 ± 6.82	.628	.645	.977	***	***	***
	U1-NA (°)	22° ± 4°	24.03 ± 5.12	24.31 ± 5.99	24.39 ± 5.98	.879	.868	.992	***	***	***
	U1-NA (mm)	4 mm ± 1 mm	2.65 ± 1.88	3.57 ± 1.86	3.61 ± 2.16	.572	.633	.953	**	***	***
	IMPA (°)	90° ± 5°	86.8 ± 6.32	87.75 ± 6.17	87.94 ± 6.36	.891	.874	.993	***	***	***
	L1-NB (°)	25° ± 4°	22.07 ± 4.63	22.06 ± 5.48	22.12 ± 5.67	.706	.733	.993	***	***	***
	L1-NB (mm)	4 mm ± 1 mm	3.55 ± 1.51	3.81 ± 1.63	3.89 ± 1.8	.314	.401	.930	NS	*	***
SOFT TISSUE	E Line (mm)	–4 ± 2 mm	-3.95 ± 1.65	-4.02 ± 1.67	-4.26 ± 1.74	.543	.503	.946	**	**	***
	S Line (mm)	0±1 mm	-0.51 ± 1.61	-1.16 ± 1.72	-1.24 ± 1.73	.793	.729	.915	***	***	***
	Nasolabial Angle (°)	102°–110°	108.33 ± 9.73	106.68 ± 10.01	106.48 ± 10.2	.866	.863	.988	***	***	***

SD Standard Deviation; NS: Not significant; *P*: Results of ICC; * *P*<0.05, ** *P*<0.01, *** *P*<0.001

Soft Tissue Measurements: A statistically significant and high level of agreement was observed between all method pairs in E Line, S Line, and nasolabial angle measurements ($p<0.001$).

Discussion

With rapid advances in computer technology, the prevalence of digital systems in cephalometry is increasing, and accuracy and reproducibility are the most fundamental criteria for these methods. In this context, the current study aimed to compare the accuracy of manual, digital, and artificial intelligence (AI)-based cephalometric analysis methods. There is a consensus in the literature that cephalometric software programs reduce measurement errors that may occur during manual drawings.[16,17] The findings of this study support this view and provide detailed results regarding the performance of AI-based systems.

The key finding of our study is that AI-based measurements exhibit a high level of correlation with manual and digital methods, particularly for skeletal and dentoalveolar parameters. Statistically significant and strong agreement was found between all methods for skeletal angles such as SNA, SNB, SN-GoGn, and dentoalveolar measurements such as overjet, overbite, and incisor angulations (U1-FH, U1-SN, IMPA, etc.). These results are consistent with many studies in the literature and support findings that AI-based software is not significantly different from manual methods in terms of accuracy in cephalometric analyses.[18,19,20] The strong agreement demonstrated by AI systems with

digital methods confirms that these technologies are a reliable alternative for clinical routines.

However, one of the most striking findings of the study is that the performance of AI-based systems in soft tissue analyses varies depending on the type of malocclusion. While the nasolabial angle yielded consistent results across all groups, no significant correlation was found between the manual and digital methods, or between the digital and AI methods, for parameters assessing lip position, such as the E Line and S Line, in individuals with Class I malocclusion. However, high agreement was observed for the same parameters in Class II and III groups. This suggests that the anatomical norms referenced by AI algorithms may not yet be fully mature enough to produce consistent results across different skeletal and soft tissue profiles. Therefore, clinicians should interpret soft tissue assessments of AI systems more carefully, especially in Class I cases.

Another important point observed in the analyses is the inconsistencies arising from the identification of certain anatomical landmarks. As previous studies have reported, difficulties in determining landmarks such as nasion and gonion can lead to errors. A specific reason for this discrepancy may be that the relevant software uses the GoMe plane instead of the GoGn plane for GoGn-SN measurement.[21,22,23] This was particularly observed in Class III patients in our study. While such an algorithmic limitation affects the accuracy of the results, it is a problem that can be addressed by manually correcting the landmark by the user.

In conclusion, this study demonstrates that AI-based cephalometric analyses are a powerful and reliable alternative to manual and digital methods in the assessment of skeletal and dentoalveolar parameters. However, their performance in soft tissue analyses can vary depending on the type of malocclusion and can lead to some errors. Soft tissue discrepancies directly affect not only aesthetics but also functional harmony. The literature emphasizes that skeletal corrections are not reflected exactly in the soft tissues and that individual differences play an important role in clinical outcomes.[24,25] Therefore, while AI systems provide significant efficiency in clinical decision-making, the results must be critically reviewed and interpreted by the clinician.

Conclusion

This study demonstrates that AI-based cephalometry is a valid and powerful tool for today's orthodontic practice. Evaluation of three different malocclusions revealed that the artificial intelligence method showed higher diagnostic accuracy compared to traditional techniques. Its high sensitivity, particularly in skeletal and dentoalveolar analyses, and its reduced analysis time make this technology highly efficient. Furthermore, WebCeph's ability to be used on any computer, without being tied to a specific computer, and its low cost make it a significant advantage.

Ethics Committee Approval

This study was approved by the Clinical Research Ethics Committee of the relevant university (Decision No: 172, Date: 16.09.2025) and was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent

Informed consent was obtained from all participants involved in the study.

Author Contributions

Conceptualization: E.A.; Data collection: Ö.F.S.; Analysis and interpretation: M.H.B.; Manuscript writing: E.A.; Final approval: All authors.

Conflict of Interest

The authors declare no conflict of interest related to this study.

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