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Precision Assessment of Cephalometric Analysis Software in Orthodontics

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Abstract

Background: Orthodontic treatment prediction and monitoring heavily rely on cephalometric analysis and measurements of skull characteristics utilizing lateral cephalograms.
Objectives: The study aimed to evaluate and compare two commercially available artificial intelligence software that offer cephalometric analysis with manual cephalometric analysis. The null hypothesis of the study is that artificial intelligence-powered tools for cephalometric analysis and manual cephalometric analysis will be accurate and interchangeable.
Materials and Methods: The study sample included 60 lateral cephalometric radiographs from a database of pre-orthodontic patient data. A cephalometric analysis was performed on the sample using cephalometric artificial intelligence software (WebCeph and easyceph) and manual method for 12 selected landmarks. A one-way ANOVA was employed for comparison.
Results: The mean values of 12 measured parameters for 60 samples were within the normal values of these measured parameters. The comparison indicated non-significant differences between the two artificial intelligence software and manual cephalometric analysis for all measured parameters.
Conclusions: The study concluded that the cephalometric analysis using cephalometric artificial intelligence software (WebCeph and easyceph) offered the same level of precision as manual tracing. Instead of the traditional methods, it might be used for a wide range of orthodontic analyses because it can save time and effort for the orthodontist. However, more research is needed to provide strong evidence for its use in clinical and research fields.
Keywords: cephalometric analysis, Orthodontics, lateral cephalograms, cephalometric software

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1. Introduction

In orthodontics, cephalometric analysis is still an essential tool (Hans et al., 2015). Cephalometric analysis helps assess dentofacial proportions, determine the anatomic cause of malocclusion, and examine changes brought on by growth and treatment. When there is a skeletal discrepancy, cephalometric analysis is regarded as a crucial diagnostic technique for orthodontic/orthognathic treatment planning (Forsyth et al., 1996, Pittayapat et al., 2014). It enables precise evaluation of the cranial base, maxilla, and mandible in both vertical and sagittal dimensions. It involves performing exact linear and angular measurements between predetermined landmarks using X-ray lateral cephalograms of the head and face (Devereux et al., 2011, Hwang et al., 2021). Traditionally, cephalometric analysis and tracing are performed manually by orthodontists which requires precise determination and measurement of various anatomical landmarks, lines, and angles on the lateral cephalometric radiographs (Kim et al., 2020, Bevans, 1933). Manual cephalometric analysis has significant limitations such as operator dependency, variability in landmark identification, time consuming, and may be tedious. Even skilled orthodontists' analyses have high intrareader variability (Nishimoto et al., 2020). Recently, with the development of artificial intelligence programs that have begun to be used in various medical fields, including cephalometric radiographs and the possibility of analyzing them, more accurate measurements and faster analysis have been offered. Also, it is easier, facilitates data exchange, and enables standardized assessment with improved reproducibility (Aksakallı et al., 2016, Erkan et al., 2012). Furthermore, it eliminates the need to prepare and store hardcopies of radiographs and radiographic analysis, instead providing a digital copy to the dental practice and patients (Nouri et al., 2015). Cephalometric analysis techniques based on artificial intelligence can be either fully or semi-automated. Artificial intelligence is used in the fully automated method to calculate the cephalometric measures, trace, and locate landmarks. On the other hand, the semi-automatic approach combines the two approaches, i.e., manually choosing landmarks and then automatically calculating values. Cephalometric analysis is also made easier these days by smartphone apps (Yassir et al., 2022, Shrestha and Kandel, 2020). These computerized programs may, however, have certain drawbacks, such as inaccuracies brought on by the radiograph's quality, magnification errors, and adjustments to the image's density, contrast, and quality. Additionally, the majority of these programs are somewhat pricey (Nouri et al., 2015, Chen et al., 2000). The computer programs need to be precise and dependable. Since the software has become publicly accessible and frequently applied in orthodontic treatment, it is vital to evaluate its precision to determine which kind is best (Shettigar et al., 2019).

The study aimed to evaluate and compare two commercially available artificial intelligence software that offer cephalometric analysis (WebCeph and easyceph) with manual cephalometric analysis. The null hypothesis of the study is that artificial intelligence-powered tools for cephalometric analysis and manual cephalometric analysis will be accurate and interchangeable.

2. Materials and Methods

2.1 Study Sample

The study used a systematic randomization procedure to choose 60 lateral cephalometric radiographs from a database of pre-orthodontic patient data. Every radiograph was taken with the same equipment (MyRay) using a routine procedure that involved placing the patients in the cephalostat with their teeth in centric occlusion, the sagittal plane at a right angle to the X-ray path, and the Frankfort plane parallel to the floor. To reduce random mistakes the sample eligibility requirements, include: high-quality radiographs that allow for landmark identification; no impacted, not-erupted, or absent incisor teeth; and no craniofacial deformities.

2.3 The Process of Cephalometric Analysis

The study employed the following measurements:

Upper lip to E-line (UL to E-line), lower lip to E-line (LL to E-line), SNA, SNB, ANB, Interincisal Angle, Facial Angle (FH-N-Pog), Facial Taper (Na-Gn-Go), Upper Incisor to Maxillary Plane, Lower Incisor to Mandibular Plane, Occlusal Plane to SN Angle (SN/OcP) and Mandibular Plane Angle (Go-Gn to SN).

Initially, cephalometric radiographs were traced manually with a sheet of tracing paper firmly placed over the cephalometric radiograph and viewed on a view screen. To prevent bias, a single examiner traced the cephalometric radiographs.

Following that, the cephalometric radiographs were uploaded to the studied cephalometric artificial intelligence software (WebCeph and easyceph).

2.4 Statistical Analyses

Version 26 of SPSS was utilized for every statistical analysis. The Shapiro-Wilk test, Levene's test, minimum, maximum, mean, and SD were used to describe the data. Typically, inferential statistics employ a 95% confidence interval. Statistical significance was established when the P-value was less than 0.05. A one-way ANOVA was employed for comparison.

3. Results

The descriptive statistical analysis including minimum, maximum, mean, standard deviation, and Shapiro-Wilk test, is shown in Table 1. The mean values of 12 measured parameters for 60 samples were within the normal values of these measured parameters (Upper lip to E-line (UL to E-line), lower lip to E-line (LL to E-line), SNA, SNB, ANB, Interincisal Angle, Facial Angle (FH-N-Pog), Facial Taper (Na-Gn-Go), Upper Incisor to Maxillary Plane, Lower Incisor to Mandibular Plane, Occlusal Plane to SN Angle (SN/OcP) and Mandibular Plane Angle (Go-Gn to SN)).

Based on the Shapiro-Wilk test, which revealed that the P value for every measurement was higher than the significance threshold of 0.05, the data met the normality criteria within the 5% significance level. The results of Levene's test showed that the data were homogenous. So, a parametric test is used for comparison.

One-way ANOVA indicated non-significant differences between the two artificial intelligence software and manual cephalometric analysis for all measured parameters as demonstrated in Table 2.

Table 1. Descriptive statistics of cephalometric measurements.

Variables	Analysis tools	N	Minimum	Maximum	Mean	SD	Shapiro-Wilk test (p value)
UL to E-line	WebCeph	60	1.9	5.0	3.65	1.15	0.141
	easyceph	60	2.0	6.0	3.87	1.24	0.152
	Manual	60	1.5	5.0	3.90	1.06	0.689
LL to E-line	WebCeph	60	0.0	3.1	1.61	1.05	0.403
	easyceph	60	0.1	3.0	1.58	0.93	0.576
	Manual	60	0.0	3.0	1.42	0.98	0.455
SNA	WebCeph	60	71	89	80.2	5.45	0.981
	easyceph	60	73	87	80.25	4.75	0.613
	Manual	60	71	90	80.14	5.75	0.987
SNB	WebCeph	60	71	85	78.78	3.99	0.954
	easyceph	60	70	86	78.89	4.91	0.936
	Manual	60	70	85	78.67	4.79	0.839
ANB	WebCeph	60	-2	8	3.3	3.05	0.883
	easyceph	60	-3	7	3.2	3.25	0.645
	Manual	60	-3	8	3.1	3.21	0.974
Interincisal Angle	WebCeph	60	123	150	134	9.22	0.397
	easyceph	60	121	150	133.6	9.52	0.559
	Manual	60	122	150	133.8	9.28	0.594
Facial Angle	WebCeph	60	81	98	88.2	5.26	0.746
	easyceph	60	80	98.5	88.25	5.71	0.942
	Manual	60	80	99	88.3	6.07	0.865
Facial Taper	WebCeph	60	51	77	64.9	8.45	0.607
	easyceph	60	50	77	64.7	8.35	0.784
	Manual	60	51	77.5	65.15	8.39	0.699
Upper Incisor to Maxillary Plane	WebCeph	60	91	124	106.2	9.94	0.997
	easyceph	60	90	125	106.3	10.31	0.988
	Manual	60	91	125	106.6	10.17	0.987
Lower Incisor to Mandibular Plane	WebCeph	60	80	111	95.1	9.25	0.999
	easyceph	60	80	112	94.9	9.33	0.999
	Manual	60	80	111	94.7	8.88	0.996
Occlusal Plane to SN Angle	WebCeph	60	11	25	17	4.75	0.803
	easyceph	60	11	25	16.5	4.69	0.535
	Manual	60	11	24	16.6	4.67	0.463
Mandibular Plane Angle	WebCeph	60	22	41	32.1	6.79	0.487
	easyceph	60	21	40	31.83	6.58	0.450
	Manual	60	22	40	31.8	6.26	0.541

Table 2. Comparison of cephalometric measurements of two software and manual tracing.

UL to E-line	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.368	2	0.184	0.134	0.875
Within Groups	43.820	32	1.369		
Total	44.187	34			
LL to E-line	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.653	2	0.327	0.354	0.705
Within Groups	26.754	29	0.923		
Total	27.407	31			
SNA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.297	2	0.148	0.005	0.995
Within Groups	766.189	26	29.469		
Total	766.486	28			
SNB	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.477	2	0.238	0.012	0.988
Within Groups	504.489	26	19.403		
Total	504.966	28			
ANB	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.439	2	1.719	0.185	0.832
Within Groups	241.389	26	9.284		
Total	244.828	28			
Interincisal Angle	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.421	2	0.211	0.002	0.998
Within Groups	2356.889	26	90.650		
Total	2357.310	28			
Facial Angle	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.030	2	0.015	0.000	1.000
Within Groups	875.281	26	33.665		
Total	875.310	28			
Facial Taper	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.860	2	0.930	0.013	0.987
Within Groups	1895.347	26	72.898		
Total	1897.207	28			
Upper Incisor to Maxillary Plane	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.404	2	1.202	0.011	0.989
Within Groups	2771.389	26	106.592		
Total	2773.793	28			
Lower Incisor to Mandibular Plane	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.966	2	0.983	0.011	0.989
Within Groups	2261.000	26	86.962		
Total	2262.966	28			
Occlusal Plane to SN Angle	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.855	2	1.427	0.064	0.938
Within Groups	578.456	26	22.248		
Total	581.310	28			
Mandibular Plane Angle	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.859	2	0.430	0.010	0.990
Within Groups	1158.589	26	44.561		
Total	1159.448	28			

* The mean difference is significant at the 0.05 level.

4. Discussion

Lateral cephalograms are essential to dental practice, whether in orthodontics or pediatric dentistry. For orthodontics, the identification of anteroposterior and vertical discrepancies, as well as the evaluation of the connection between soft tissue and dental tissue, depends on the lateral cephalometric radiograph (Aksakallı et al., 2016, Pittayapat et al., 2014). Therefore, the cephalometric analysis method must be precise, secure, and repeatable (Celik et al., 2009). In the present day, manual cephalometric tracing is rapidly being replaced by computerized cephalometric tracing systems. The use of apps based on smartphones has increased recently (Shettigar et al., 2019, Aksakallı et al., 2016). The clinical experience and skills of orthodontists are very important in the exact determination of anatomical landmarks and tracing of radiographs (Baumrind and Frantz, 1971). On the other hand, artificial intelligence-powered software may reduce human mistakes by automating the process of landmark determination. Furthermore, such cephalometric software could enhance the reproducibility and decrease variability in the landmarks determination (Lee et al., 2020, Hwang et al., 2021).

WebCeph is among the few readily available apps that easily obtained from the Google Play store and used with all of the modern Android-powered smartphones. It can automatically conduct cephalometric analysis and help organize patient information in accordance with a standard (Yassir et al., 2022, Baig et al., 2024).

The easyceph software is one of the online available digital cephalometrics. Steiner and the six traditional Ricketts superimpositions are available and also developed a framework that lets orthodontists program their own superimpositions. Additionally, can export the cephalometric data in an executable format for spreadsheet software so that orthodontists can perform their research and compare the cephalograms.

The WebCeph software was examined by some previous studies but with controversial conclusions (Yassir et al., 2022, M Azeez et al., 2023, Chuchra et al., 2024, Prince et al., 2023, Silva et al., 2024) and to the researcher's knowledge, no previous research had been conducted concerning easyceph software to evaluate it. So, the performance of these two software should be evaluated and their accuracy must be confirmed before it can be authorized for clinical and research usage.

In the present study, twelve cephalometric parameters frequently used in orthodontics were selected to evaluate the cephalometric software (Akhare et al., 2013). The present study's findings showed that there were non-significant differences between cephalometric artificial intelligence software (WebCeph and easyceph) and manual cephalometric analysis. These results agree with some previous studies that take different types of cephalometric software. Mohan et al, 2021, conducted a study to evaluate the precision and dependability of angular and linear measures derived from manual tracings in lateral cephalometry and OneCeph digital cephalometric tracing. This study concluded that OneCeph is an easy-to-use, dependable, and accurate substitute for manual tracing that is accessible via a smartphone without requiring an internet connection, saving clinicians time and resources (Mohan et al., 2021). Also, another study examined the accurateness of angular and linear values for 23 parameters and found no statistically significant difference between the two procedures utilized which were analyzed manually and using application-based software (OneCeph) for most parameters (Barbhuiya et al., 2021). Azeez et al., 2023 reached to conclusion that WebCeph's digital tracing is comparable to manual cephalometric tracings and appropriate for clinical applications. The benefits of digital imaging regarding storage, transmission, and improvement quality may make it the preferred option for daily usage and study over analog techniques (M Azeez et al., 2023). Similar results were found when compared WebCeph to manual tracing by Mahto et al., 2022 (Mahto et al., 2022).

However, on the other hand, another study revealed a statistically significant difference in accuracy between two artificial intelligence-based software alternatives and the traditional digital technique, although these differences were not clinically relevant outside of certain parameters. Semi-automated tracing was quicker than traditional tracing and more accurate than automatic tracing. Confirming software accuracy in cephalometric tracing will require more investigation (Mercier et al., 2024). Also, a recent study compared between study compares WebCeph and AutoCAD computer software. This study found various issues inherent in the automatic WebCeph, including inconsistent measurements and poor landmark identification/soft tissue tracing (Yassir et al., 2022). Additionally, when compared to manual digital tracing, artificial intelligence assisted cephalometric analysis tools like WebCeph, WeDoCeph, and CephX result in significant differences in accuracy and dependability, particularly when it comes to angular and linear measurements. These findings highlight how crucial it is to carefully choose and evaluate analysis techniques for orthodontic diagnosis and treatment planning (Bor et al., 2024).

The main reasons for the controversy about WebCeph and other artificial intelligence cephalometric software include concerns about the accuracy of landmark detection, variations among software platforms, and the specific limitations of each tool. Research indicates that WebCeph performs well on several popular cephalometric tests, although its reliability in more complex scenarios is still debatable. The distinctions between different study techniques and the needs of clinical versus research applications complicate the topic. To ensure that these cephalometric tools meet the accuracy requirements needed for both clinical and research applications, it will be essential to continuously validate and standardize them as Artificial intelligence technology advances.

Artificial intelligence has become increasingly prevalent in orthodontic diagnostics in recent years. This potential technique makes it easier to trace cephalometric landmarks in routine clinical applications, which could help little expertise doctors plan orthodontic treatments and reduce the amount of time spent on radiological patient diagnosis. Artificial intelligence is expected to be further incorporated and developed for orthodontic applications (Kiełczykowski et al., 2023, Dipalma et al., 2023).

5. Conclusions and Recommendations

For every measured parameter, the comparison showed non-significant differences between the two artificial intelligence programs and manual cephalometric analysis. According to the study's findings, manual tracing and cephalometric analysis utilizing cephalometric artificial intelligence software (WebCeph and easyceph) provided an equivalent level of accuracy. Instead of the traditional methods, it might be used for a wide range of orthodontic analyses because it can save time and effort for the orthodontist. However, more research is needed to provide strong evidence for its use in clinical and research fields.

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