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Comparison between Manual Lateral Cephalometric Analysis and Artificial Intelligence Driven Platforms

Hatem Saifeldin[1]

Aim: It remains uncertain whether artificial intelligence-based programs can detect cephalometric landmarks with accuracy. Therefore, the aim of this prospective study was to compare cephalometric measurements obtained with manual tracing and artificial intelligence programs. An additional goal was to evaluate the difference in cephalometric tracing duration.

Materials and methods: Fifty pretreatment lateral cephalometric radiographs with complete permanent dentition were included in this study. Poor quality radiographs, irregular shaped incisors roots, craniofacial deformity and/or impacted teeth were excluded. Each lateral cephalogram was traced and analysed using manual method, WebCephand Cephio programs. After completion of landmark plotting, linear and angular measurements of Steiner'sanalysis were calculated.

Results: The results indicated the presence of no statistically significant differences between the three methods. SNA, SNB and ANB angles had a relatively higher values with WebCeph compared to Cephio and manual cephalometric analysis. On the other hand, mandibular plane angle and occlusal plane angle were higher withCephio when compared to WebCeph and manual methods. The duration taken for cephalometric measurements showed statistically significant difference between manual cephalometric analysis and AI based programs with WebCeph presenting the least duration and manual method showing highest duration.

Conclusion: The cephalometric measurements obtained from both WebCeph and Cephio programs are highly accurate when compared to manual measurements. Cephalometric measurements done using WebCeph and Cephio are formulated in a significantly shorter time in comparison to manual method.

Keywords: Cephalometric analysis; WebCeph; Cephio; artificial intelligence

1. Associate professor of Orthodontics, Orthodontic Department, Faculty of Dentistry, Ain Shams University.
Corresponding author: Hatem Saifeldin, email: hatemsaifeldin@dent.asu.edu.eg

INTRODUCTION

Lateral cephalometric radiographic analysis is one of the essential diagnostic records for identifying skeletal, dentoalveolar and soft tissue disproportions.[1] To identify such discrepancies, lateral cephalometric radiographs should be traced and analyzed.

The conventional method for cephalometric analysis uses a layer of acetate tracing sheet taped to the lateral cephalometric radiograph, and with the use a view box, identification of the cephalometric landmarks is done manually then linear and angular measurements are completed with a pencil, ruler and protractor.[2] This manual technique is the gold standard for cephalometric analysis, yet, it is time consuming due to the longsome steps related to it.[3]

Recently, there has been increasing interest in using artificial intelligence (AI) and machine learning (ML) in the dental field.[4] Among the various applications of this technology in orthodontics was to develop a fully automatic cephalometric analysis capable of reducing the burden of manual cephalometric analyses.[5] Computerized software and web based cephalometric application can self-generate the landmarks on the digital lateral cephalometric radiograph and finish the analysis using artificial.

Research in the past revealed that automated cephalometric analysis programs showed greater number of errors compared to manual tracing thus giving minimal evidence to scientifically aid their application in orthodontics.[6] Recently, some studies[5,7] have shown that AI based cephalometric analysis programs are showing promising results in comparison to manual technique and could be a practical option for lateral cephalometric tracing and analysis. Still, it is necessary to confirm the accuracy of any AI based cephalometric analysis systems before they are widely used in clinical practice.[4] Inaccurate identification of cephalometric landmarks may lead to erroneous decision-making in orthodontic treatment planning. A fully automated and accurate identification of the cephalometric landmarks is always desired.[8]

Despite the variety of AI based programs available for automated cephalometric analysis, it remains uncertain if they are able to trace cephalometric landmark with accuracy. There is a need to assess the accuracy of these commercially available programs to allow the orthodontist to decide the suitable software for accurate cephalometric measurements.

Therefore, the aim of this prospective study was to compare cephalometric analyses acquired with manual tracing and two AI web-based programs. Another aim of this study was to calculate the difference in the duration taken to finish the conventional manual technique and AI driven programs.

MATERIALS AND METHODS

Experimental Design

This was a prospective randomized study. Randomization was done using a computer software. Ethical approval for this study was submitted to the Faculty of Dentistry, Ain Shams University Ethical Committee. No changes were conducted to the methods after study commencement.

Sample Size Calculation

The sample size consisted of fifty pretreatment lateral cephalometric radiographs. They were obtained from the out-patients clinic, Faculty of Dentistry, Ain Shams University. The sample size was determined by G* power program according to a previous study by Mohan et al[3] where the power was set at 80% and the significance level to 0.05.

Sample characteristics

Those who matched the following criteria were taken in: All lateral cephalometric radiographs were for subjects who had complete permanent dentition. Their age range was between 18 to 24 years. The exclusion criteria were: patients with unerupted or missing teeth, poor quality of radiographs, irregular shape of incisors roots, craniofacial deformity and/or impacted teeth.

Methods

Standardized digital lateral cephalometric radiographs were filmed with the same x-ray machine (Vatech, Hwaseong, Korea). This machine utilizes a charged-couple sensor chip for image reception. The exposure guidelines for the digital cephalography were 70kV, 10mA and 12.9seconds. Cephalometric radiograph was taken in centric occlusion with lips rested. The patients stand in natural head position with the red-line of the machine labelling the Frankfort horizontal plane (FH) parallel to the flooring.

The lateral cephalometric radiographs were exported in JPG format. Each participant radiograph was traced manually then digitally using two AI web-based lateral cephalometric analysis programs: WebCeph and Cephio. Each radiograph was traced both conventionally and digitally using AI programs then analyzed by the same orthodontist. To prevent any inaccuracy due to eye fatigue, only five radiographs were traced per day. The duration to finish the analysis using each technique was recorded using a digital stopwatch.

Manual tracing

Manual tracing was done using high-definition prints of digital cephalometric radiographs. Manual tracing was done on a view-box (Dentaurum, Ispringen, Germany) in a dark room. The tracing was carried out on a 8" x 10" acetate tracing paper sheets secured over the radiograph prints with adhesive tape and traced by hand using a 0.5mm mechanical pencil. A ruler with a protractor was then utilized to draw and calculate the linear and angular landmarks of Steiner's cephalometric analysis.[9]

Digital tracing

Each cephalogram digital JPG image was designated a number and then saved to the MacBook Pro used in this study before being uploaded to the WebCeph and Cephio websites. After logging in the website of each program using a web-browser (Safari), a new patient file was generated and a lateral cephalogram JPG image was imported to the programs. Correction of any magnification was done using a 10mm distance inbetween two points on the cephalostat arm in the cephalogram After calibration of the images, all landmarks for Steiner's analysis were detected using AI option on each software automatically by the same orthodontist. After this step, the measurement of Steiner's analysis was determined by the applications. Linear and angular data from the analysis were entered into an Excel sheet.

Statistical analysis

All the data collected was filled in tables and analyzed statistically using IBM SPSS Statistics. Descriptive statistics (mean and standard deviation values) was calculated for each method of cephalometric analysis. Test for data normality was analyzed using Kolmogorov-Smirnov and Shapiro-Wilk tests. Groups comparison was computed with a one-way analysis of variance. When significant differences were present, Post hoc test (Tukey HSD) determined which mean was significantly different from others. The significance level was set as $P < 0.05$, and a 95% confidence interval was estimated for the outcomes in groups of the study.

Method Error

After ten days of the initial measurements done in the study, ten cephalograms were randomly selected and the measurements were repeated to detect any intra-operator error using a paired T-test.

RESULTS

The descriptive statistics for cephalometric measurements for all groups are presented in (table 1). Kolmogorov-Smirnov showed that collected data are normally distributed.

The results of the analysis of variance (ANOVA) comparing the skeletal and dental measurements for the three methods showed that there were no statistically significant differences between them (P>0.05). The SNA, SNB and ANB angles had a relatively higher value when using WebCeph program in comparison to Cephio and manual cephalometric analysis. On the other hand, the mean value of mandibular plane angle and occlusal plane angle was higher with Cephio in comparison to WebCeph and manual cephalometric analysis. On the contrary, the duration taken for cephalometric measuremens showed a highly statistically significant difference between manual cephalometric analysis and AI based programs with the least duration taken to finish the analysis when WebCeph (30.6 ± 3.4 s) was used and manual tracing (484 ± 23.3 s) required the maximum duration of time (table 2).

Table (1): Descriptive statistics for cephalometric measurements and results of one way ANOVA

Cephalometric measurement	Manual analysis Mean & standard deviation	WebCep analysis Mean & standard deviation	Cephio analysis Mean & standard deviation	*P* value
SNA (◦)	83.42±3.81	84.31±3.87	83.29±3.23	0.693
SNB (◦)	80.01±2.40	80.93±2.14	79.32±2.84	0.781
ANB (◦)	3.08±3.82	4.42±2.36	3.49±2.24	0.456
SN-MP (◦)	31.45±5.12	30.11±6.17	32.33±4.20	0.554
U1-NA (◦)	31.33±7.64	30.67±8.43	30.41±7.65	0.534
U1-NA (mm)	7.10±3.43	7.86±2.99	6.89±3.10	0.463
L1-NB (◦)	35.07±6.01	35.41±6.32	35.32±6.04	0.1967
L1-NB (mm)	8.69±3.12	7.70±2.83	7.30±2.91	0.176
Occlusal plane (◦)	15.78±5.56	16.01±5.16	16.12±6.01	0.453
Interincisal (◦)	126.13±7.81	127.20±7.10	126.29±8.01	0.198

Table (2): Time duration for each method of cephalometric analysis

Group	Mean and standard deviation	Tukey test*
Manual ceph analysis	484±23.3	a
WebCeph	30.6±3.4	b
Cephio	32.1±2.1	b
*significant (p<0.05)		

*Groups with different letter are different significantly from each other at p<0.05.

DISCUSSION

Digital techniques for lateral cephalometric analysis are gaining popularity everyday. Whether the program is computer or web-based, the tracing should be accurate, and this is the most important factor to be considered before working with any of the digital programs in the market. Therefore, in our study, we conducted a comparison for the accuracy of cephalometric analysis done using conventional method two commercially available AI based programs for lateral cephalometric analysis. WebCeph and Cephio programs are both web-based and only an internet browser is needed to log in and perform the analysis. The choice of Steiner's analysis for our study was due to the fact that it is widely implemented cephalometric analysis with different linear and angular measurements both skeletal and dental.[9] All tracings, landmarks identification and analysis measurement were done by the same operator as it was reported that the experience of the orthodontist is an important element that can prevent any errors with landmark identification on cephalograms.[10]

The main result of our study was that WebCeph and Cephio, artificial intelligence-based programs, were as accurate for cephalometric analysis as manual technique. These fully automated programs are precise and extremely fast, once the cephalogram is uploaded to the program, data processing, landmark identification and analysis measurement are automatically computed. On the other hand, the manual technique requires a viewer box, pencil, acetate paper, ruler and protractor to accomplish the same job. The findings of this study are in concordance with those obtained by Mohan et al[3] who found that the OneCeph software application was as reliable and accurate as conventional tracing. Also, Alqahtani[11] showed that the artificial intelligence based software (CephX) was comparably accurate and reliable to semi-automated program

(FACAD). On the other hand, MeriÃ et al[13] showed that CephX needed more improvements to be reliable. Moreover, Yassir et al[12] found that WebCeph suffered from poor landmark identification and inconsistency of measurements. Yet, Yassir et al[12] only compared WebCeph measurements to those of another program (AutoCAD) and no manual tracings were included in the study.

Regarding the time consumed to perform manual and digital cephalometric analysis, there was a high significant difference between the automated and manual methods. Artificial intelligence-based programs computed the cephalometric analysis in an extremely short time. About 16 digital cephalometric analyses can be finished in the time needed for 1 manual cephalometric analysis. Moreover, the cephalometric data recorded by the web-based programs can be stored, recovered and used at any time, saving time and space needed for radiographic storage. Therefore, our study demonstrated that WebCeph and Cephio can compute cephalometric analysis with accuracy in comparison to conventional manual tracing and in a much shorter duration.

CONCLUSION

From this study we can conclude that:

1. The cephalometric analysis driven from WebCeph and Cephio programs are accurate when compared to conventional manual measurements.
2. Cephalometric measurements done using WebCeph and Cephio are formulated in a significantly shorter time in comparison to manual method.

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