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Original Article

The Accuracy of A Newly Developed Mobile Application "Pediceph" Versus Conventional Cephalometric Analysis in The Diagnosis of Dental and Skeletal Deformities Among Pre-Adolescent Patients: A Diagnostic Accuracy Study

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Abstract

Aim: This study aims to evaluate the accuracy of a newly developed mobile application versus the conventional hand tracing method of cephalometric analysis in the measuring of dental and skeletal cephalometric measurements among children and pre-adolescent patients.
Subjects and Methods: Thirty-one cephalometric x-rays of children and pre-adolescent patients (8-13) years old were traced manually (reference test) and by using the Pediceph mobile application (index test) to detect its accuracy. The intraobserver and interobserver reliability were calculated.
Results: Comparisons between the two tests revealed insignificant differences in all measurements with P>0.05. Interobserver reliability (inter Class Coefficient) revealed excellent agreement (ICC = >0.9), and intraobserver reliability (inter Class Coefficient) revealed excellent agreement (ICC = >0.9), very good agreement (ICC=0.8-0.9) for all measurements
Conclusion: Pediceph is an accurate orthodontic diagnostic tool capable of performing cephalometric tracing procedures. It saves time and reduces errors.

Keywords: Cephalometry, mobile application, orthodontic diagnosis.

Introduction

The interaction between all the components of the masticatory unit, such as the teeth and their supporting structures, the neuromuscular system, the temporomandibular joints (TMJs), and the craniofacial bone, is known as occlusion. This relationship is considered dynamic, morphological, and functional. **(Davies, 2022)**.

Any divergence from the previously defined typical pattern of occlusion resulting from abnormalities in the dynamic process of craniofacial growth and development is referred to as malocclusion. Malocclusion is a public health problem affecting patients' quality of life. It can affect patients' physical and psychological health. Socially, malocclusion affects attractiveness and social acceptance (**Georgina et al., 2023)**.

The American Association of Pediatric Dentistry (AAPD) mentioned the importance of monitoring the development of dentition till

reaching a stable, functional, and aesthetically accepted occlusion. It highlighted the role of diagnosis and early management of any developed condition in achieving the desired occlusal harmony **(AAPD, 2022)**.

Lateral cephalometric x-ray is the main tool in orthodontic planning and analysis of different malocclusion disorders. It analyses the relationship between dental, skeletal, and facial structures, thus helping reach the proper diagnosis. The objective of the cephalometric analysis is to compare a patient's measurements obtained from a cephalogram versus the 'standard values' **(Nielsen, 2022)**.

Roentgen introduced the cephalometric radiograph; since then, it has been considered the primary tool in orthodontic planning and analysis of different malocclusion disorders. The cephalometric analysis is used to study the relationship between dental, skeletal, and facial structures (**Pałka et al, 2022)**.

Manual tracing of lateral cephalometric radiographs is considered the gold standard tracing technique. Despite that, it is prone to errors that may affect the whole treatment plan, andthese errors may be in the landmark identification due to using bad-quality tracing paper, which masks fine details, or using poor lighting devices (**Qadir & Mushtaq, 2017 ; Hlongwa, 2019)**.

The introduction of computers into the medical and research field paved the way for the revolution in the tracing procedure. This aimed to increase the capability of analyzing more population samples and the facility of norm determination. Advances in computer software have allowed for an accurate analysis of patients' cephalometric records (**Polat-Ozsoy et al., 2009)**.

With the innovation of the smartphone and its operating software and mobile applications or "apps",the cell phone has become an easily used, palm-sized computer **(Mohan et al., 2018)**. The availability of this kind of technology helps improve diagnostic quality, perform efficient treatment plans, and predict the prognosis, thus increasing the ability to make proper clinical decisions **(Bonabi et al., 2019)**.

Several studies were conducted to evaluate the accuracy and reliability of mobile applications in cephalometric tracing. These mobile applications were found to be effective diagnostic tools in orthodontic treatment planning **(Barbhuiya et al., 2021)**.

The mobile application 'Pediceph' is an Egyptian attempt to perform cephalometric analysis based on Egyptian norms. This study aims to evaluate the accuracy of this newly developed mobile application, ' Pediceph ', in cephalometric analysis versus the manual tracing technique.

Subjects and Methods

Study Design and Setting

The present study was a diagnostic accuracy study conducted in the Pediatric Dentistry and Dental Public Health and Orthodontics Departments, Faculty of Dentistry, Cairo University, Egypt. The study protocol was registered on the clinical trial website (http://www.clinicaltrial.com.gov) with protocol ID: NCT05070676.

Sample Size Calculation

Thirty-one Lateral cephalometric X-ray records of children and pre-adolescent patients were evaluated in the current study. The sample was calculated based on the results of **(Shrestha & Kandel, 2020)** . A power analysis was created to have sufficient power to apply a two-sided statistical test of the null hypothesis that there is no difference between the investigated techniques. An alpha level of (0.05), a beta of (0.2), i.e. power=80%, and an effect size (d) of (0.734) were adopted.

Eligibility Criteria

Lateral Cephalometric x-ray records of children and pre-adolescent patients (8-13) years old were collected from the Orthodontic Department of the Faculty of Dentistry, Cairo University according to the following criteria:

1. Cephalogram of good quality with all landmarks clearly visible.
2. Presence of central incisors and first molars on cephalogram.
3. Cephalogram with teeth in maximum intercuspation.

To avoid any bias in the selection process, an orthodontist who was not involved in the study and was unaware of the need for the radiographs performed the selection of the cephalograms.

Test Methods

1. Development of Pediceph Mobile Application:

The mobile application **(PediCeph)**, was developed in native Android (Java programming language), with Android Studio as the IDE (Integrated Development Environment), by an Egyptian developer **Ahmed Abd El-mohsen (A.A.) and Randa El-Behiery (R.A.)**.

The layout of the application was developed using Adobe Illustrator® software. In addition, the mobile application's logo, brand, objects, and shapes were designed to enable the resizing of the images without any loss of quality due to the wide range of scales available in current smartphones.

PediCeph was designed with an interface suitable for easy tracing procedures, allowing the clinician to locate the anatomical landmarks easily.

2. Lateral Cephalometric Tracing:

All thirty-one cephalometric radiographs are traced with both conventional hand tracing methods and using the Pediceph mobile application. The hard anatomical landmarks used in the tracing procedures are mentioned in the following table (1) (**Hlongwa, 2019)**.

The following planes are traced:

a. SN plane (Straight line through point S and point N).
b. MP Mandibular plane (Straight line through Menton (Me) and Gonion (Go)).
c. NA-line (Straight line through Nasion and A - point).
d. NB-line (Straight line through Nasion and B - point).
e. Lines through the long axis of the upper and lower incisors.

The measured angles were:

a. Angle SNA° (the angle between points S, N, and A).
b. Angle SNB°(the angle between SN line and NB line).
c. Angle ANB° (the difference between SNA° and SNB°).
d. Angle U1-NA° (the anlgle between long axis of U1 and NA line).
e. Angle U1-NB° (the angle between long axis of L1 and NB line).
f. Interincisal angle (the angle between long axis of U1 and L1).
g. Angle between SN line and Mandibular plane.
h. Angle between L1 and Mandibular plane.

A. The Index Test (Pediceph Mobile Application):

The angles used by "Pediceph" in the cephalometric analysis of mixed dentition were SNA, SNB , ANB, SN-MP, U1-L1, U1-NA, L1-NB, L1-MP. The lateral cephalometric angles were calculated using Egyptian norms, based on the results of an Egyptian master thesis, for norms of mixed dentition stage **(Afifi, 1982)**.

Procedure for Cephalometric Analysis Using PediCeph:

1-The first step was to start uploading the cephalometric x-ray by pressing 'Open photo' to select a photo from the Gallery stored on the mobile device.
2- After the photo was selected. The patients' age was entered.
3- Once the image is loaded, it was magnified and zoomed to obtain maximum visibility for fine details. This was done easily by a slight finger gesture. Scrolling through the image was also done to ensure a convenient yet accurate tracing procedure by dragging it in the desired direction.
4-For the linear measurement of wits appraisal, A known distance was marked on a built-in ruler is an important step; so by selecting 'Mark on cephalogram' from the side menu, PediCeph asked to locate a starting point and end one on the ruler, to start calibrating the marked distance in millimeters scale.
5-The landmarks needed were selected for tracing. On touching the X-ray at the required anatomical position, the point was highlighted in red colour. This point was adjusted using UP and DOWN, RIGHT, and LEFT arrows at the bottom of the screen. By selecting 'NEXT', the point position was locked and changed to green colour, then proceeding to the next landmark
6-After finishing the landmark detection, the result was shown on a screen for swipe-up. The result contains the normal value of each angle, its mean value, and the interpretation of each reading, showing a primary diagnosis, as shown in Figure (1).

B. Reference Test (Manual Tracing Method):

Manual tracing of lateral cephalometric radiographs can be accomplished with a pencil and high-quality tracing paper attached to the cephalometric radiograph in a dimly lit room, mounted on a viewer. Points can be marked, planes can be drawn, and angles can be measured in millimeters with a protractor and ruler **(Hlongwa, (2019)**.

Technique:

a. On the lateral cephalometric radiograph, the tracing paper was positioned correctly.
b. On the tracing paper the patient's name, age, and date of radiograph was written.
c. Using adhesive tape, the tracing paper was secured to the top edge of the radiograph.
d. The hard tissue (HT) structures were traced, and identified the following hard tissue landmarks, as shown in Figure (2).

e. The results were placed on an Excel sheet, and statistical analysis was performed.

3. Intraobserver Reliability:
To detect the intra-observer reliability, the sample of the cephalometric x-ray was checked twice using the reference and index tests with the same observer, with a week interval in between.

4. Interobserver Reliability:
To assess the inter-observer reliability, the sample of the cephalometric X-ray was checked twice using both the reference and index tests by another investigator **Hadeer Ayman (H.A.)** other than the main investigator.

Statistical Methods

Statistical analysis was performed with SPSS 20®, Graph Pad Prism®, and Microsoft Excel2016. All quantitative data were explored for normality by using Shapiro Wilk and Kolmogorov normality test. Independent t-test was used to compare the measurements by manual and digital methods. Interobserver and intraobserver reliability were evaluated using ICC (interclass correlation coefficient).

Table (1): Hard anatomical landmarks used in cephalometric tracing

Sella (S)	The mid-point of sella turcica
Nasion (N)	The junction of the most anterior point of the frontonasal suture
A-point	The deepest point on the maxilla below ANS
B-point	The most posterior point on the bony curve of the mandible above pogonion
Menton (Me)	The lowest point on the symphysis of the mandible
Gonion (Go)	The most posterior and inferior point on the outline of the angle of the mandible
Gnathion (Gn)	The most outward and everted point on the profile curvature of the symphysis of the mandible, located midway between pogonion and menton
Pogonion (Pg)	The most anterior point on the contour of the chin

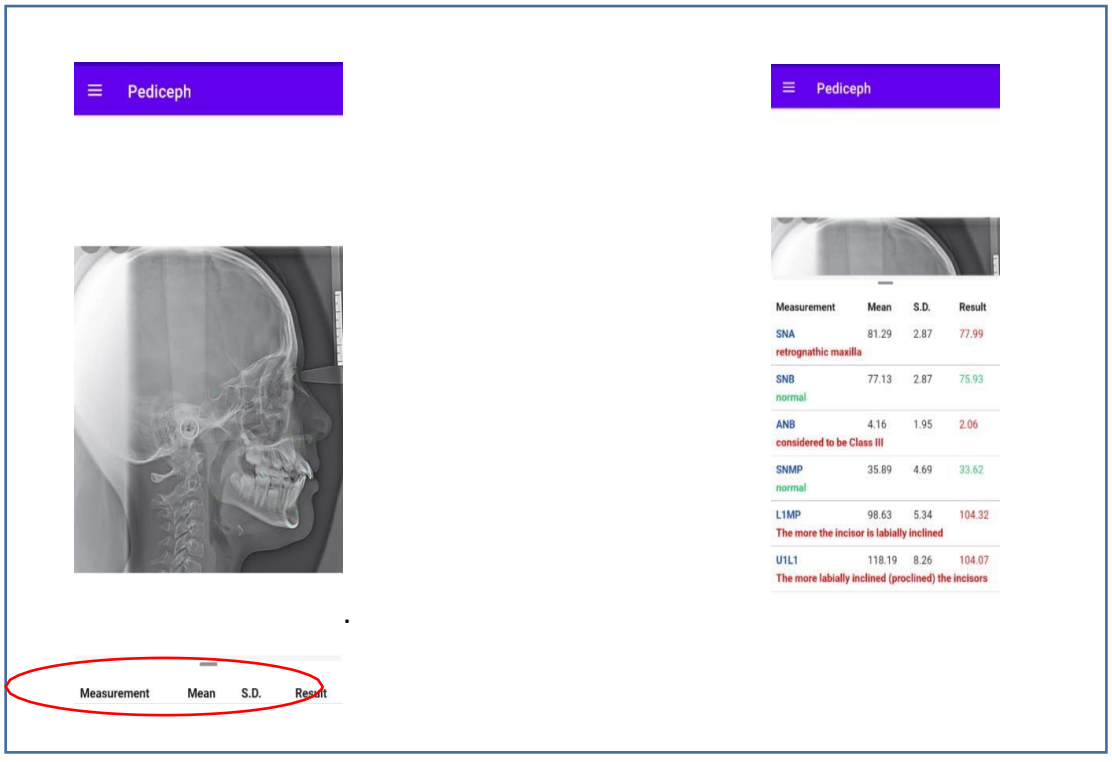

Figure (1): Pediceph interface showing the results after finishing the tracing

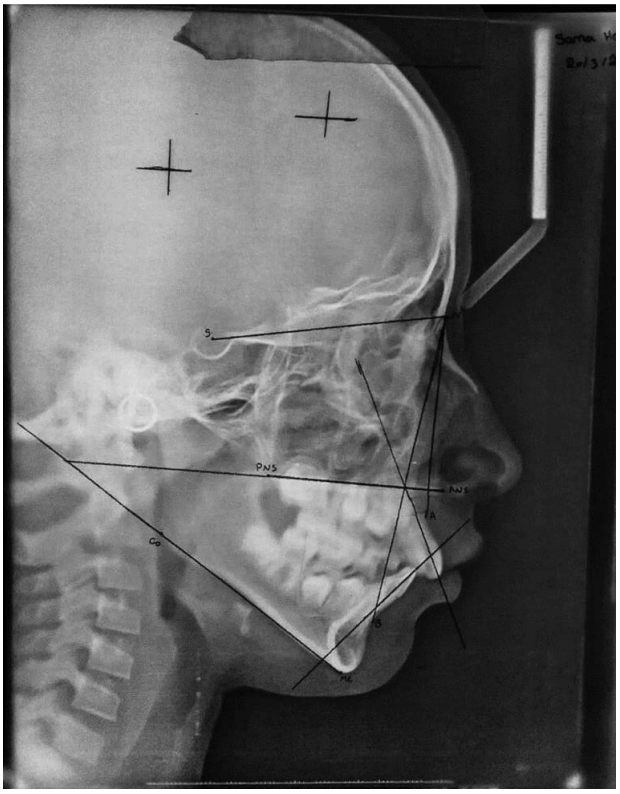

Figure (2): Photograph showing a cephalometric x-ray on the viewer traced by the manual method.

Results

The data of both groups measurements (the index test and the reference test) showed a normal distribution (parametric data) resembling the normal bell curve.

The comparison between the measurements of the reference and index tests showed an insignificant difference between them in all measurements as P>0.05. The mean and standard deviation of the cephalometric measurements of both tests are presented in table (2). Interobserver reliability (inter Class Coefficient) revealed excellent agreement (ICC = >0.9), and intraobserver reliability (inter Class Coefficient) revealed excellent agreement (ICC = >0.9), very good agreement (ICC=0.8-0.9) for all measurements.

Table (2): Comparison between reference and index tests using Independent t-test.

	Reference test		Index test		Difference (Independent t-test)				
					Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
	M	SD	M	SD			Lower	Upper	
SNA	80.69 [c]	4.67	81.11 [c]	4.86	-0.42	1.19	-2.80	1.96	0.72
SNB	77.59 [c]	5.02	78.12 [c]	4.76	-0.53	1.22	-2.97	1.92	0.67
ANB	3.09 [c]	4.74	2.99 [c]	4.65	0.10	1.17	-2.24	2.45	0.93
SN-MP	36.73 [c]	5.31	36.77 [c]	5.32	-0.03	1.33	-2.69	2.62	0.98
U1-L1	118.08 [c]	15.71	118.61 [c]	15.88	-0.53	3.95	-8.42	7.36	0.89
U1-NA	28.69 [c]	14.07	28.41 [c]	14.22	0.27	3.54	-6.80	7.34	0.94
L1-MP	95.17 [c]	8.05	94.98 [c]	8.04	0.20	2.01	-3.83	4.22	0.92
L1-NB	29.92 [c]	7.54	30.00 [c]	7.86	-0.08	1.93	-3.93	3.77	0.97

Discussion

The ability of a test to distinguish between those who have and do not have the condition or disease of interest is known as its accuracy test, and it is a crucial component in the evaluation of diagnostic tests **(Sitch et al., 2021)**. Therefore, the current work aimed to determine the accuracy of the newly developed mobile application (Pediceph) in digital cephalometric tracing.

The index test selected was a mobile application developed in native Android (Java programming language). Native Android was believed to have better performance, enabling the developers to use the device's full capabilities. It is available to be downloaded via the application stores. Java is presently one of the most common languages in the world and consequently has one of the largest universal communities **(Ahmad et al.,2018; Wasilewski & Zabierowski, 2021**.

The reference test was the manual tracing method. Manual tracing is the oldest and most widely used method and the gold standard method of cephalometric tracing. It includes placing a sheet of tracing paper over the cephalometric radiograph, detecting landmarks, and creating linear and angular measurements between landmark locations using a ruler, compass, and protractor (**Kotuła et al., 2022)**.

To enhance the landmark identification process, the same operator undertook all the digital and manual tracings twice in one-week intervals to minimize the chance of error. Only two x-rays were traced each day to prevent observers' eye fatigue, which can alter landmark recognition and compromise the data obtained, affecting the reliability of the study **(Sreedevi et al., 2022)**.

A second observer was allowed to manually trace all the cephalometric X-rays and use the application to detect the interobserver's reliability. Reliability is the ability to repeat the results consistently. Where in the two researchers compare their data after separately observing the same behavior (to prevent bias). If the data are comparable, it is reliable **(Chugh et al., 2023)**.

The results of this study data showed no statistically significant difference between the readings of all cephalometric angles obtained by manual tracing method and using the Pediceph mobile application. This finding aligns with **Shrestha & Kandel, 2020; Mohan et al., 2021; Khader et al., 2022**, comparing the manual cephalometric analysis readings to the Oneceph mobile application readings.

Regarding the evaluation of intra-observer reliability, the results of this study revealed excellent agreement (ICC = >0.9) in all measurements. This is consistent with **Sheratha and Kandil, 2020,** who mentioned that the ICC values for intra-examiner reliability for all cephalometric measurements with the manual method and Mobile application OneCeph ranged between 0.910 and 0.998.

This study measured the inter-observer reliability by assessing the results of the index test and reference test obtained by the first observer and the results obtained by the second observer. It revealed excellent agreement (ICC = >0.9) between all parameters. This aligns with (**Chung et al., 2023)** interobserver reliability (reproducibility) of the two measurement methods. Interobserver reliability was classified as "excellent" (ICC) value >0.90) for all measurements.

The present study is considered an initial study, and further research is recommended to evaluate this new application. Although the Pediceph application demonstrated the ability of a smartphone to simplify a complex, time-consuming diagnostic task such as cephalometric analysis, various updates in PediCeph software are needed to facilitate the tracing process.

Conclusion

The study results showed that digital cephalometric tracing is an easy and accurate method of orthodontic diagnosis. The app-based cephalometric analysis (PediCeph) could be considered an accurate chair-side cephalometric analysis method with the same accuracy as the manual tracing.

Conflict of interest: No Conflict of interest.

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Ethics:
The study protocol was revised and agreed by the Research Ethics Committee of the Faculty of Dentistry, Cairo University, on 22-2-2022, with an approval number 8-2-22.

Clinical Trial Registration:
The study protocol was registered on the clinical trial website (http://www.clinicaltrial.com.gov) with protocol ID: NCT05070676.

Data Availability:
Data will be available upon request.

Credit Statement:
Author 1: Data curation, Writing-original draft, Methodology, Conceptualization, Resources.
Author 2: Data curation, Conceptualization, Project administration, Supervision, Methodology, Writing - review & editing, Writing - original draft.

Author 3: Methodology, Writing - original draft, Writing - review & editing, Investigation, Formal analysis, Supervision, Data curation.

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