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Assessment of Recent Smartphone Applications For Different Cephalometric Analysis in Orthodontics (A Comparative Study)

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ABSTRACT

Aim: To assess the validity and reliability of cephalometric measurements performed by CephNinja, OneCeph and EasyCeph applications with lateral cephalometric radiographs based on measurement obtained from veiwbox computer software. **Subjects & methods:** 50 patients' pre-treatment lateral cephalograms using the same digital cephalometer were collected. Patients were traced twice using three mobile apps (i.e., CephNinja and OneCeph, Easyceph), with Viewbox used as the reference standard computer software program. 11 angular and 2 linear measurements originating from the Downs analysis, Ricketts analysis and Wits appraisal. **Results:** There were no statistically significant differences were found between the mobile application and computer software which states a strong validity and agreement between the two readings. **Conclusion:** Smartphone cephalometric analysis applications perform satisfactorily in terms of validity and reliability. OneCeph is highly valid when compared with Viewbox as a control group than other two mobile apps, while both mobile apps Oneceph and CephNinja are more reliable than Easyceph.

KEYWORDS

Smartphone applications; cephalometric analysis, OneCeph Easyceph, CephNinja

INTRODUCTION

Cephalometrics is a component of clinical orthodontics and orthognathic surgery that aims to assess dentofacial proportions, clarify the anatomic basis of a malocclusion, and analyses growth and treatment-related changes [(1)]. Manual cephalometric analysis has been largely replaced by semiautomatic computer-based software [(2)] , which allows for direct landmark identification on digital images displayed on a screen. Similarly, newly released apps software applications designed to run on smartphones and tablets enable automatic calculation of cephalometric measurements following manual landmark identification [(3)].The adoption of mobile technologies by healthcare professionals has been associated with several advantages, including improved practice productivity and clinical decision making, rapid access to information and multimedia resources, and more accurate

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patient documentation[4]. There is mounting evidence to support the efficacy of teledentistry, or the combination of telecommunications and dentistry in the exchange of clinical information and images between distant locations for remote dental consultation and treatment planning [5]. Currently available orthodontic apps are targeted either at clinicians or patients and are intended to promote orthodontic news, meetings, products, diagnostics, practice management or to serve as patient education materials, treatment simulators, progress trackers, and elastic wear reminders[6-8]. Nevertheless, a systematic approach to evaluating the accuracy and evidence base of mobile apps is at this point lacking[8]. Most of the relevant studies refer to established criteria for assessing healthcare information displayed on websites and not specifically for apps [9]. Consequently, a decision to embed a health care app in everyday practice should be thoroughly explored[10]. Earlier research on the validity of smartphone cephalometric analysis apps operating on tablets and smartphones compared with manual and computerized cephalometric analysis has yielded contradictory results [11-13]. Given the exponential growth of apps and the current lack of a systematic approach to evaluate the validity and reliability of mobile apps, monitoring of the measurement properties of apps is needed. Therefore, the aim of this study was to assess the concurrent validity and reliability of cephalometric measurements generated by three popular, free apps: CephNinja (version 5.07**,** , Naveen Madan, Bothell,Wash) and OneCeph (version 9, NXS, Hyderabad, Telangana, India), EasyCeph (version 11.2 ,Android 5.0, Dr. Rajajee,India) compared with Viewbox (version 4.1.0.12 64bit, dHAL Software, Kifissia, Greece) as the reference standard.

MATERIALS AND METHODS

Sample size calculation was done first to determine the size of the sample , the Power analysis (G*Power software,lastest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) showed that a sample size of at least 50 patients would give an 85% probability of detecting a real difference of 0.2 mm between groups at a statistically significant level of 10 % , the sample included 50 pretreatment digital lateral cephalograms of male and female patient who attended the orthodontics clinic located in the faculty of dental medicine – Al-Azhar University Assuit branch, Assuit, Egypt.

No selection criteria were applied in relation to patient's gender, age, and type of malocclusion. All radiographs were obtained using the same radiographic unit according to a standardized protocol. Patient identifiers (i.e., name, age, gender, and date of examination) were cropped out of the original lateral cephalograms to maintain patient privacy. Each radiograph was taken with the patient oriented in neutral head position and the radiographs without projection errors. The lateral radiographs were obtained at the same x-ray unit (the NewTom™ Giano 2D imaging system Aperio, Sarasota, FL, USA) and by the same technician. The latest versions of the OneCeph (group A) CephNinja (group B) and EasyCeph (group C) mobile apps were downloaded from the Google Play Store (Google Inc., Mountain View, Calif.) on A Samsung Galaxy Note 20 ultra smartphone (Samsung Telecommunications, Suwon, South Korea) (14-18),was installed as the reference standard on a laptop (Microsoft Surface Laptop Core i8, 8-256 GB, Microsoft Corporation, Redmond, Wash). To eliminate interobserver variability and concentrate on inter tool variability, a single examiner traced the radiographs at random using Viewbox **(Fig. 1)**, One-Ceph **(Fig. 2)** [15], CephNinja **(Fig. 3)**[14,16] and finally EasyCeph **(Fig. 4).** All tracings were repeated in random order in a second session, 2 weeks after the first one. Tracing periods were set at 1 hour to prevent operator fatigue. Prior to the study, a 3-hour training session was carried out to allow the examiner to master the tracing method. As the vast majority of smartphones are not equipped with a stylus, identification of landmarks was performed directly on the touchscreen by a finger to represent mainstream use. To define the cephalometric variables, a total of 13 landmarks will be digitized .11 angular and 2 linear measurements originating from the Downs analysis [17], Ricketts analysis [19] and Wits appraisal [20], the prevailing cephalometric analysis in orthodontic practices (2) all available in the analysis protocols of Viewbox and the mobile apps, that will be selected for the tracing procedures, namely, the facial angle, angle of convexity, A-B angle, mandibular plane angle and Y axis of (Downs analysis), facial axis, MD plane to FHP, facial taper angle, lower facial height, mandibular arc, palatal plane to FHP, maxillary convexity (mm) (Ricketts analysis), and AO-BO the perpendiculars drawn from point A and B on the occlusal plane of intersecting cusp of premolars and molars (mm) (wits appraisal).

Statistical Analysis

Statistical analyses will be performed and the validity of the mobile apps (i.e., the degree to which an outcome measure measures the construct it purports to measure) will be estimated by comparing the first session measurements of each app to the reference standard (i.e., Viewbox) using repeated measures analysis of variance. A clinically relevant difference claimed when the angles and distances measured by the apps differed by >2º or > 2 mm, respectively. [21, 22]. The reliability of the apps (i.e., the degree to which the measurement is free from measurement error) will be determined using paired t-test and the limits of agreement on measurements acquired by the three programs by comparing the result of the 1st session of cephalometric analysis with the result of the 2nd session.

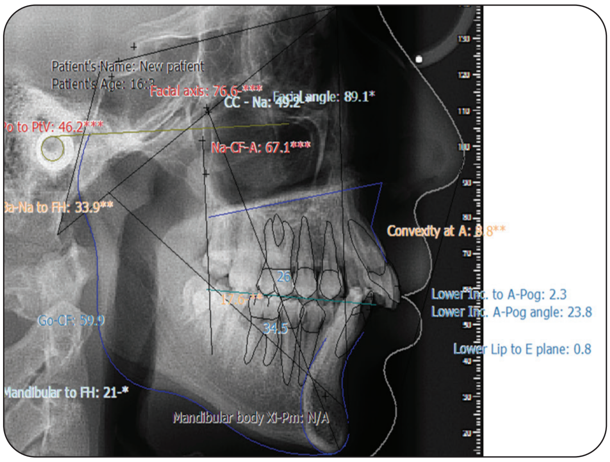

Fig. (1) Veiwbox

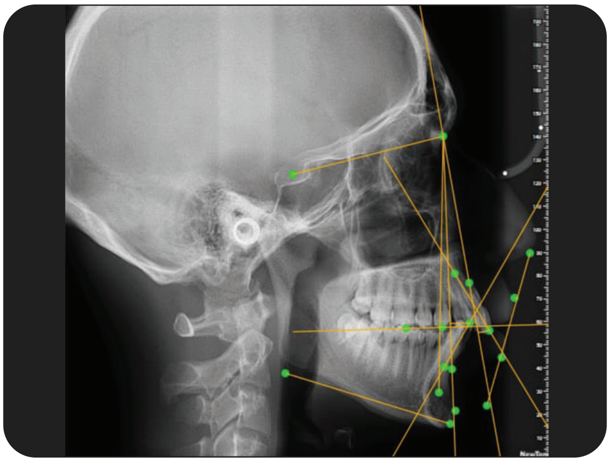

Fig. (2) Oneceph

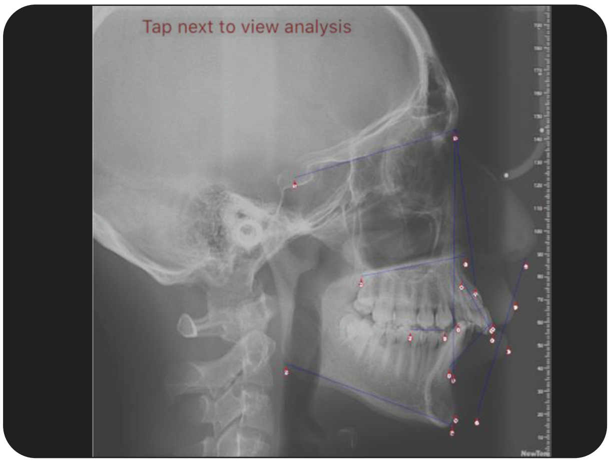

Fig. (3) CephNinja

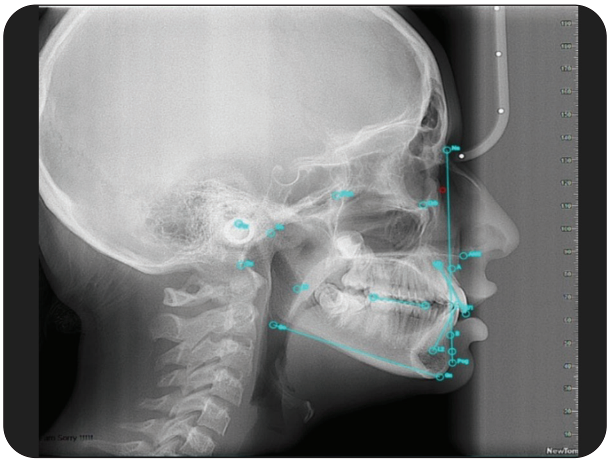

Fig. (4) Easyceph

RESULTS

The mean and standard deviation values were calculated for each group in each test and recorded in tables (1-4) while Fig. 5 showed the graphical representation of the obtained results. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data showed parametric (normal) distribution. One-way ANOVA followed by Tukey post hoc test was used to compare between more than two groups in non-related samples for quantitative data. A paired sample t-test was used to compare between two groups in related samples. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Table (1) *The mean, standard deviation (SD) values of different groups.*

Variables	Accuracy								p-value
	Group A (One-Ceph)		Group B (Ceph-Ninja)		Group C (Easy-Ceph)		Control (View-box)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
The facial angle 1st session	89.96	2.86	89.46	3.71	90.00	2.71	89.22	2.61	0.489ns
Angle of convexity 1st session	7.63	0.44	7.14	0.74	7.46	0.46	7.44	0.33	<0.001*
AB angle 1st session	9.08	0.92	8.04	0.95	7.60	1.21	9.32	1.62	<0.001*
Mandibular plane angle 1st session	18.86	6.07	20.78	3.28	18.40	2.27	20.38	2.23	0.004*
Y axis 1st session	57.30	5.04	57.57	5.69	57.20	5.36	58.18	5.42	0.800ns
Facial axis 1st session	88.40	7.50	89.63	7.47	91.60	6.05	88.64	7.53	0.106ns
MD plane Frankfort horizontal plane 1st session	18.46	1.66	20.95	2.51	18.40	2.76	19.44	1.95	<0.001*
Facial taper 1st session	68.14	3.10	67.89	3.04	66.14	3.36	67.82	3.31	0.008*
Lower facial height 1st session	37.68	7.73	37.49	7.94	39.80	4.84	37.70	8.41	0.350ns
Mandibular arc 1st session	40.34	5.48	43.17	3.92	37.80	3.34	41.32	4.06	<0.001*
Palatal plane to FH 1st session	5.20	0.47	5.26	0.74	4.70	0.33	5.14	0.64	<0.001*
Maxillary convexity mm 1st session	3.88	0.13	4.30	0.60	3.65	0.62	4.46	0.84	<0.001*
Wits appraisal mm 1st session	6.56	0.58	5.52	0.36	5.99	0.55	5.82	0.62	<0.001*

Table (2) *The mean and standard deviation (SD) values of the 1st and 2nd session of Group A.*

Variables	Accuracy Group A (One-Ceph)				p-value
	First session		Second session		
	Mean	SD	Mean	SD	
The facial angle	89.96	2.86	88.90	3.15	<0.001*
Angle of convexity	7.63	0.44	7.35	0.80	0.106ns
AB angle	9.08	0.92	8.12	0.58	<0.001*
Mandibular plane angle	18.86	6.07	18.36	2.05	0.632ns
Y axis	57.30	5.04	57.52	5.74	0.204ns
Facial axis	88.40	7.50	88.56	8.07	0.157ns
MD plane Frankfort horizontal plane	18.46	1.66	18.10	2.83	0.414ns
Facial taper	68.14	3.10	69.04	4.09	<0.001*
Lower facial height	37.68	7.73	40.08	8.13	<0.001*
Mandibular arc	40.34	5.48	39.54	5.68	0.012*
Palatal plane to FH	5.20	0.47	4.64	0.21	<0.001*
Maxillary convexity mm	3.88	0.13	3.20	0.47	<0.001*
Wits appraisal mm	6.56	0.58	6.18	1.36	0.133ns

Table (3) *The mean and standard deviation (SD) values of the 1st and 2nd session of Group B.*

Variables	Accuracy Group B (Ceph-Ninja)				
	First session		Second session		p-value
	Mean	SD	Mean	SD	
The facial angle	89.46	3.71	88.46	3.37	<0.001*
Angle of convexity	7.14	0.74	6.39	0.87	<0.001*
AB angle	8.04	0.95	6.15	1.20	<0.001*
Mandibular plane angle	20.78	3.28	21.43	3.54	<0.001*
Y axis	57.57	5.69	58.39	5.66	<0.001*
Facial axis	89.63	7.47	87.81	8.40	<0.001*
MD plane Frankfort horizontal plane	20.95	2.51	20.51	3.66	0.181ns
Facial taper	67.89	3.04	68.09	3.68	0.091ns
Lower facial height	37.49	7.94	37.64	8.23	0.225ns
Mandibular arc	43.17	3.92	42.76	3.43	<0.001*
Palatal plane to FH	5.26	0.74	5.42	1.60	0.351
Maxillary convexity mm	4.30	0.60	4.64	0.75	0.018*
Wits appraisal mm	5.52	0.36	6.96	1.36	<0.001*

Table (4) *The mean and standard deviation (SD) values of the 1st and 2nd session of Group B.*

Variables	Accuracy Group C (Easy-Ceph)				
	First session		Second session		p-value
	Mean	SD	Mean	SD	
The facial angle	90.00	2.71	90.40	3.97	0.115ns
Angle of convexity	7.46	0.46	7.40	0.81	0.733ns
AB angle	7.60	1.21	7.00	1.11	<0.001*
Mandibular plane angle	18.40	2.27	18.40	2.36	1ns
Y axis	57.20	5.36	57.80	5.25	<0.001*
Facial axis	91.60	6.05	90.80	6.11	<0.001*
MD plane Frankfort horizontal plane	18.40	2.76	18.40	6.25	1ns
Facial taper	66.14	3.36	66.92	3.47	<0.001*
Lower facial height	39.80	4.84	41.20	5.83	0.011*
Mandibular arc	37.80	3.34	38.80	3.02	<0.001*
Palatal plane to FH	4.70	0.33	4.64	0.81	0.603ns
Maxillary convexity mm	3.65	0.62	3.45	0.37	0.001*
Wits appraisal mm	5.99	0.55	6.27	0.44	0.001*

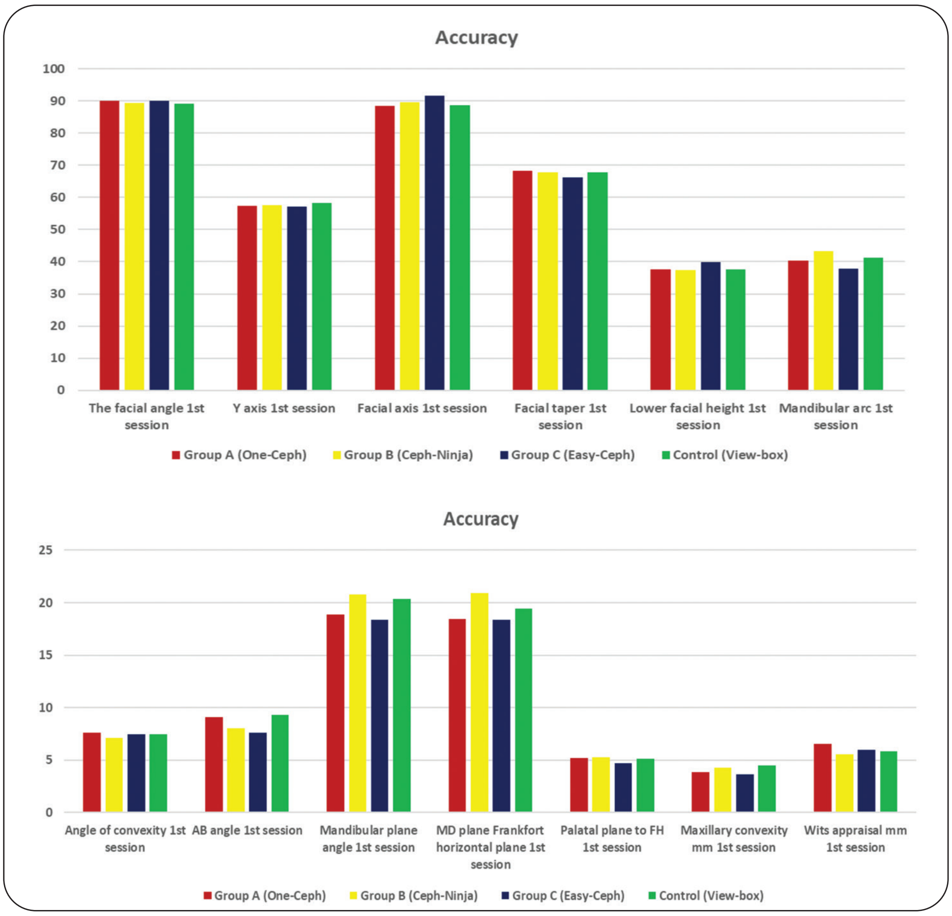

Fig. (5) Bar charts representing relation between different groups.

DISCUSSION

For a very long period of time, the manual tracing method was the only method available for cephalometric analyses [23]. The problem with this traditional approach is that it is time consuming and prone to errors due to the limitations of the human eye, Additionally, the smallest scale on a conventional instrument is the millimeter for linear measurements and is the degree value for angular measurements, which limits the accuracy of such tools [17].

Developments in technology have led to the rising use of digital cephalometric analysis systems, which have several advantages: radiation doses are reduced, data storage is improved, and images are easily manipulated [18]. Regardless of whether the chosen technique is digital or a smartphone app, it is essential that it be reliable, safe, precise, and have a high rate of reproducibility [24]. Our study has provided analytical assessment of the validity and reliability of linear and angular cephalometric measurements obtained by OneCeph, CephNinja and Easyceph apps. Overall, both cephalometric analysis apps performed satisfactorily, suggesting the potential use of easy-to-reach digital technology to make cephalometric more readily accessible(1). There isn't much research that looked at the reproducibility of smartphone cephalometric apps in the literature, and the ones that did tend to focus on iPhone apps (Apple Inc., Cupertino, Calif). The study by Sayar and Kilinc [13] examined the reproducibility of the CephNinja 3.10 app, which runs on Apple's iPhone operating system (IOS), in comparison with the hand-tracing method. For all tested measures, they discovered substantial statistical differences, although the differences were clinically nonsignificant. In 2010, Paixão et al.,[23] study compared the angular and linear cephalometric measurements obtained through manual and digital cephalometric tracings using Dolphin Imaging® 11.0 software with lateral cephalometric radiographs. The results showed no statistically significant differences in any of the assessed measurements (p>0.05), and they conclude that: the Conventional and computerized methods showed consistency in all angular and linear measurements [21]. Chen, Piaxo and Sobral found no significant differences in any of the measurements. Acquired with digital cephalometric tracing and manual cephalometric tracing, which is in line with our study [17] . Another study argued that one method to control errors in the replication of cephalometric measurements consists in calibrating examiners directly, and further suggest that such direct calibration be included in any scientific experiment. They compare between measurements taken by the examiner in manual and digital cephalometric tracings at different times showing that no statistically significant difference was found in any of the measurements in both groups[19]. On the other hand, Aksakalli et al.,[12] investigated the accuracy of two cephalometric apps, CephNinja 3.3 and SmartCeph Pro 1.1, which run on the iPad (Apple Inc.), and they compared those apps with the computerized Dolphin imaging software. Because the majority of the measures varied greatly from the Dolphin imaging software, the authors came to the conclusion that smartphone apps should be created to deliver more accurate data[12]. In 2009 Celik et al.,[24] and Sayinsu et al., [20] reported significant differences in N I to Pog measurements, which might have arisen from the fact that the porion is an inconsistent cephalometric point [18].

Despite the previously reported explanations regarding the differences in SNB, N I to Pog, and U lip to S line measurements between the tracing methods, the intra-examiner reliability in the present study was high for both tracing techniques. This might suggest that the landmark identification for the operator was relatively straightforward.

In 2006 a study was done by Santoro et al.[22] observed differences in ANB, SN to GoGn, U1 to NA (mm), and L1 to NB (mm) may reflect either the difficulty in locating the associated cephalometric points or technical discrepancies between the two apps. Inconsistencies in defining the landmarks N Gn, Go, and lower incisor apex, and the linear measurements U1 to NA and L1 to NB , have been repeatedly reported for manual and computerized methods [22].

A study by Albarakati et al.,[25] reported significant differences in SNB measurements. A possible explanation for such a difference, according to previous studies, was that the nasion can be difficult to locate precisely when the nasofrontal suture is not clearly visualized.

Regardless of the method used, it has been reported that the gonion, porion, orbitale, lower incisor apex, and menton were the most unreliable and inconsistent points[17,18]. Additionally, the nasion, menton, and posterior nasal spine were also sources of mistakes[26].

CONCLUSION AND RECOMMENDATION

The present study on Cephone, Cephninja and Easyceph software revealed that there are no measured variables with very close results. OneCeph is highly valid when compared with Viewbox as a control group than other two mobile apps, while both mobile apps Oneceph and CephNinja are more reliable than Easyceph. The smartphone cephalometric analysis apps perform satisfactorily in terms of validity and reliability. the CephNinja, Oneceph and EasyCeph mobile apps are semi-automated programs that are more accurate than the full-automated one with less tracing errors, they also allow the clinician to zoom in, zoom out, move the point, and reposition to choose the ideal place for a landmark that is beneficial for less tracing errors. Given the exponential growth of apps and the current lack of a systematic approach to evaluate the validity and reliability of mobile apps, monitoring of the measurement properties of newest mobiles apps is needed.

Declarations

Ethical Approval

Not Applicable

Competing interests

The authors declare that they have no competing interests as defined by Springer, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

Authors' contributions

Mohamed Ahmed Mohamed Salem was responsible for the conception and the design of the study; Abubakr Mohamed Mohamed Ahmed was the operator who prepare and collect the clinical data. Hussein Shokry Hassan Ahmed was responsible for the digital radiography. Mostafa Mohamed Mahmoud Dawaba was responsible for writing the paper, revising, and proofreading the paper. All authors read and approved the final manuscript.

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Availability of data and materials

Correspondence to the corresponding author.

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تقييم تطبيقات الهواتف الذكية الحديثة للتحليلات المختلفه لأشعة الرأس الجانبية في تخصص تقويم الأسنان (دراسة مقارنة)

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الملخص :

الهدف: تقييم صحة وموثوقية قياسات الرأس التي أجراها تطبيق سيفنينجا ووانسيف وايزيسيف مع الصور الشعاعية الجانبية لقياس الرأس بناءً على القياس الذي تم الحصول عليه من برنامج الكمبيوتر فيوبوكس.

المواد والأساليب : تم جمع صور رأسية جانبية لـ 50 مريضاً قبل العلاج باستخدام نفس مقياس الرأس الرقمي. تم تتبع المرضى مرتين باستخدام ثلاثة تطبيقات للهاتف المحمول (على سبيل المثال، سيفنينجا ووانسيف وايزيسيف مع استخدام فيوبوكس كبرنامج كمبيوتر قياسي مرجعي. 11 قياسًا زاويًا وقياسين خطيين ناشئين عن تحليل داونز وتحليل ريكيتس وتقييم ويتس.

النتائج: عدم وجود فروق ذات دلالة إحصائية بين تطبيق الهاتف المحمول وبرمجيات الكمبيوتر مما يدل على صدق قوي واتفاق بين القراءتين.

الخلاصة: أداء تطبيقات تحليل قياسات الرأس بالهواتف الذكية مرضٍ من حيث الصلاحية والموثوقية. يعد وانسيف صالحًا للغاية عند مقارنته بـ فيوبوكس كمجموعة تحكم مقارنة بتطبيقي الهاتف المحمول الآخرين. في حين أن كلا من تطبيقات الهاتف المحمول وانسيف وسيف نينجا أكثر موثوقية من ايزيسيف.

الكلمات المفتاحية: تطبيقات الهواتف الذكية الحديثة , أشعة الرأس الجانبية ,تطبيق سيفنينجا ووانسيف وايزيسيف