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The validity reliability and reproducibility of the smartphone application as compared to manual cephalometric analysis

Abstract

Introduction: The introduction of an application, especially designed for a smartphone to perform cephalometric analysis seems logical in today's era. However the reliability of these applications against manually traced cephalometric methods must be verified. Hence the aims and objective of our study was to assess the validity, reliability and reproducibility of the cephalometric measurements derived from smartphone based application as compared to manual tracings.

Materials and methods: Pretreatment lateral cephalogram were obtained from the conventional cephalostat. Tracings were done manually on acetate sheets and using CephNinja Pro for IPhone. Cephalometric landmarks and measurements were recorded and compared by the same investigator.

Results: All the measurements showed no statistically significant difference ($p>0.05$) for any of the cephalometric parameters.

Conclusion: Smartphone based cephalometric analysis is valid and shows agreeable reproducibility with manual tracing analysis and is reliable for clinical decision making.

Keywords: cephalometric analysis, smartphone application, conventional cephalometric analysis

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Introduction

Cephalometric evaluation has come a long way since Broadbent's standardization of lateral cephalometric radiographic technique in 1931.[1] Cephalometric radiography is an essential method for diagnosis and treatment planning in orthodontics.[2] For a long period of time the manual technique was the only method available for cephalometric evaluation the major disadvantage of it being minor unavoidable errors and time consuming[3]. With advancing technologies these days work should be articulate and quick hence the use of smartphone, which has applications designed for a smartphone to perform cephalometric analysis is much needed in the hour.[2]

Any new application in orthodontic field must be checked for its reliability against the conventional methods. With the same objective in mind we conducted the present study to assess the validity, reliability and reproducibility of cephalometric analysis derived from smartphone application in comparison to conventional tracing methods.

The null hypothesis stated in the study was that the results of tracings performed using a smartphone app would not be significantly different from those obtained from tracings performed by hand, but the application method would require less time.

Material and methods

Pretreatment lateral cephalometric radiographs of 100 patients were acquired from the patients visiting the department of orthodontics using Planmeca X-ray Machine. There was no discrimination in subject selection with respect to gender, type of malocclusion, or skeletal pattern. The radiographs were taken in the natural head position.

Inclusion criteria

1. High quality pretreatment lateral cephalogram
2. No history of orthodontic or surgical treatment

Exclusion criteria

1. Cephalograms with missing posterior teeth
2. Low quality images
3. Images with artifacts that would hinder the accurate identification of skeletal structures and cephalometric points.

Smartphone application cephalometric tracing method

Smartphone assisted tracing was done using CephNinja version 3.66 (Cyncronus; free download from Apple App Store) on an iPhone 7 plus. (Apple Corporation, Palo Alto, CA, USA). The same cephalogram obtained from planmeca x-ray machine were placed on an x-ray viewing box and right facing photograph of the same x-ray was taken from I phone 7 plus. These photographs were then inserted in the application, cropped flipped and rotated within the application itself as per our convenience. Before tracings, the cephalograms were calibrated using the tools within the application. Landmark identification was done using touch gesture on the iPhone. Zooming in option allowed to easily hold and drag the pins to exact positions.

After the landmarks were identified using the touch gesture within the application, with the help of these landmarks the lines and planes were then derived by the application itself to be further used in the analysis. The lines and plane hence obtained are shown in Table 1

Table 1 Linear and angular measurements used in the study

Parameters used in the study	Description
SNA	Angle between Sella-Nasion and point A
SNB	Angle between Sella-Nasion and point B
ANB	Difference between SNA and SNB.
SN- maxillary plane	Angle between S-N and maxillary plane (ANS-PNS)
Maxillary mandibular plane	Angle between ANS-PNS and Go-Gn
upper anterior facial height	Linear distance between points N and ANS
Upper incisor to maxillary plane	The angle between long axis of upper incisor to maxillary plane
Lower incisor to mandibular plane	The angle between long axis of lower incisor and mandibular plane
Inter incisor angle	The angle between the axis of upper incisor and the axis of lower incisor.
Nasolabial angle	Angle formed by drawing a line tangent to the base of the nose and a line tangent to the upper lip
Lower lip to E line	Linear measurement between the lower lip and line joining tip of the nose to the tip of the chin.
Upper lip to E line	Linear measurement between the upper lip and line joining tip of the nose to the tip of the chin.
Lower anterior facial height (LAFH)	Distance between points ANS and Me.

Figure 1 is a screenshot taken from the smartphone application cephNinja showing the various parameters used in the study. Figure 2 are the obtained measurements of the various parameters from the smartphone cephNinja application.

Figure 1 Screenshot taken from the smartphone application cephNinja showing the various parameters.

1)Point S (sella), 2) Point N (nasion), 3) Point A (A), 4)Point B (B), 5) Gonion (Go), 6) Gnathion (Gn), 7) Upper Incisor Edge (U1i), 8) Upper Incisor Root Apex (U1r), 9) Lower Incisor Incisal Edge (L1i), 10) Lower Incisor Root Apex (L1r), 11) Posterior Nasal Spine (PNS), 13) Anterior Nasal Spine (ANS), 14) Columella of the Nose (i.e. the mid-point between the subnasal point and the nose tip), 15)Upper Lip (UL), 16) Lower Lip (LL) and 17) Soft Tissue Pogonion (Pog'), 18) menton (me), 19) subnasale (Sn), 20) nasal tip (NT).

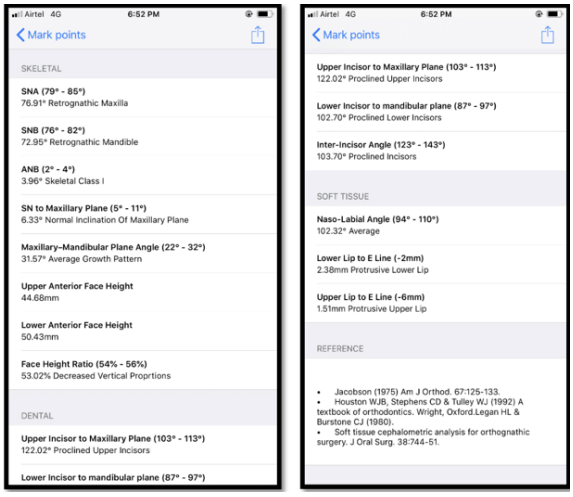

Figure 2 Showing the measurements of the various parameters obtained from CephNinja application.

Manual cephalometric tracing method

Manual tracings employed the same radiographs taken from Planmeca X-ray machine and developed on 30 x 24 cm sized cephalometric radiograph. The tracings were performed on clear acetate sheets of 0.003mm affixed to the cephalogram film and using a 2H pencil, 15 cm scale and protractor. Bilateral structures were averaged to a single landmark.

Composite analysis was adopted for cephalometric analysis due to its conglomerate measurements. The analysis involved eight skeletal measurements, three dental measurements and three soft tissue measurements. The cephalogram was labeled with 20 landmarks, namely, Point S (sella), Point N (nasion), Point A (A), Point B (B), Gonion (Go), Gnathion (Gn), Upper Incisor Edge (U1i), Upper Incisor Root Apex (U1r), Lower Incisor Incisal Edge (L1i), Lower Incisor Root Apex (L1r), Posterior Nasal Spine (PNS), Anterior Nasal Spine (ANS), Columella of the Nose (i.e. the mid-point between the subnasal point and the nose tip), Upper Lip (UL), Lower Lip (LL) and Soft Tissue Pogonion (Pog'), menton (me), subnasale (Sn), nasal tip (NT)

Magnification error

To determine magnification error or distortion of image, each radiograph was marked at four corner locations (P1, P2, P3, and P4) as fiducial points at a predetermined distance of 98 mm between P1-P2, P3-P4; and 100 mm between P1-P4, P2-P3[4] as shown in Figure 1.

Method error

The methodology was performed by the same examiner and was evaluated twice with an interval of one week difference. Assessment of intra examiner reliability was done using Kappa statistics, which showed perfect agreement (Kappa = 0.80-1.00,p<0.001)

Statistical analysis

The statistical test was done using IBM SPSS v23 software operating on windows 10.

The mean and standard deviations of the various parameters used in the study for both smartphone application tracing and manual tracing were obtained and these parameters were compared using the paired t-test.

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Pearson's correlation was applied to assess the strength of correlation between the smartphone application tracing method and the manual tracing method. A p-value of <0.05 was considered statistically significant.

Results

The mean value and standard deviation for the different parameters used in the study for both the smartphone application tracing and manual tracing are presented in Table 2. The maxillary to mandibular plane angle, facial height ratio, and upper incisor to maxillary plane, nasolabial angle and lower anterior facial height were found to be statistically greater than those for the smartphone application method as shown in Table 2. The inter incisor angle and lower lip to E line was found to be statistically lower than those for the smartphone application method which is again shown in Table 2. Table 3 shows the coefficient between the different parameters used in the smartphone application tracing and manual tracing. Karl Pearson's method has been used for correlation between the two methods and the 'r' value was found to range between 0.935-0.999 which is closer to 1 showing a positive correlation between the manual and application method.

Table 2 Comparison of mean measurements using two different measurement using paired t- test

Parameters	Method	Mean	SD	Paired t-value	p-value
SNA	Application	80.76	4.2	0.622	0.535
	Manual	80.72	4.16		
SNB	Application	76.93	4.49	0.469	0.64
	Manual	76.9	4.47		
ANB	Application	3.84	2.74	0.041	0.967
	Manual	3.84	2.71		
SN maxillary plane	Application	7.99	3.4	-1.053	0.295
	Manual	8.03	3.47		
Maxillary- mandibular plane	Application	22.22	6.09	-7.839	0.001**
	Manual	23.73	6.41		
Upper anterior facial height	Application	47.48	4.84	-1.203	0.232
	Manual	48.09	6.11		
Facial height ratio	Application	54.92	2.57	-2.553	0.012*
	Manual	55.03	2.56		
UI maxillary plane	Application	114.79	12.29	5.658	0.001**
	Manual	113.45	12.41		
LI mandibular plane	Application	98.09	8.16	1.024	0.308
	Manual	97.8	7.77		
Inter incisor angle	Application	124.84	17.4	2.259	0.026*
	Manual	124.5	17.1		
Naso labial angle	Application	105.57	12.36	4.671	0.001**
	Manual	104.69	12.08		
Lower lip to e line	Application	0.89	3.23	2.902	0.001**
	Manual	0.68	3.11		
Upper lip to e line	Application	-1.22	2.4	-0.696	0.488
	Manual	-1.17	2.37		
Lower anterior facial height	Application	57.64	7.06	-3.176	0.001**
	Manual	57.77	7.09		

*p<0.05 is statistically significant; **p<0.001 is statistically highly significant.

Discussion

CephNinja application is user friendly and portable. It also allows the operator to rotate and flip the cephalogram, as well as crop unnecessary areas of the image. The application also allows the operator to correct the position of the identified landmark after digitization. This helps in improving landmark identification, thereby minimizing the potential errors.[4] For a very long period of time, the manual tracing method was the only method available for cephalometric analyses. The problem with this traditional approach is that it is time consuming and prone to errors due to the limitations of the human eye.[5] In the present study 8 skeletal 3 dental and 3 soft tissue parameters were evaluated and compared between the application tracing method and the manual tracing method.

The findings in the study show that the SNA, SNB, ANB, SN to maxillary plane, upper anterior facial height, lower incisor to mandibular plane, and upper lip to E –line shows no significant difference between the smartphone application tracing and the manual tracing as shown in Table 2. These findings disagree with the studies done by Lance QB, et al[6] who showed that a significant difference does exists between the smartphone application tracing method and the manual tracing method though the errors are clinically acceptable. According to Lance QB, et al[6] the errors in cephalometric tracing is unavoidable even with highly experienced clinicians.

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In support to our work, Chen, et al[7] and Paixao, et al.[2] found no significant difference between the tracings done by the two methods. These authors agreed that the computerized method resulted in less error compared to the manual method and thus it is more reliable. Further it was found that maxillary to mandibular plane angle, facial height ratio, and upper incisor to maxillary plane, inter incisor angle, nasolabial angle lower lip to E line, and lower anterior facial height showed significant difference between the smartphone application and manual tracing method as shown in Table 2. In support Forsyth, et al.[4] Revealed that errors in the angular and linear measurements acquired from digital images are greater than those that occur with traditional manual tracing. Further in a study done by Gulsilay, et al[8] they have stated that these differences could be because of the fact that the manual tracing is done with a lead pencil and the difference in the width of the lines drawn by the pencil may lead to some minor errors. In a study done by Paixao, et al[2] they showed that the difference in the measurements involving the maxillary and mandibular incisors could be because dental structures are difficult to precisely identify and using the zoom in option in the application may lead to some minor differences. The differences in the mandibular plane angle could be due to overlapping structures in this area which lead to difficulty in locating the Gonion point.

In the present study a strong correlation was found between the cephalometric tracing done on cephNinja application and manual cephalometric tracing method as shown in Table 3 The inference of this study is very similar to another study conducted by Goracci C, Ferrari M.[9] Reproducibility of measurements in tablet-assisted, PC-aided, and manual cephalometric analysis. Thus conclusively reinforcing the fact that tablet or smartphone based application is reliable for cephalometric analysis and clinical decision making. Similar to our study, Prabhakar et al.[10] Compared two different computerized methods and a manual tracing method. These authors found no significant differences in the results. Similar to our study Chen, et al,[7] and Paixao et al.[2] Found no significant differences in any of measurements acquired with digital cephalometric tracing and manual cephalometric tracing. These authors argued that the computerized method resulted in a lower range of error than the traditional method and thus increased measurement reliability. In a study conducted by Gulsilay, et al[8] "Manual tracing versus smartphone application (app) tracing: a comparative study" the tracing results revealed significant differences in the majority of the measurements. They revealed that most of the measurements in app tracing method were found higher than that of the manual tracing method. In a study conducted by Kohli et al[11] they concluded that Handheld (smartphone)-assisted cephalometric analysis shows good agreement with manual tracing.

Table 3 Pearson's correlation between the measurements obtained using two methods

Parameters	r-value
SNA	0.987
SNB	0.983
ANB	0.969
SN maxillary plane	0.996
Maxillary mandibular plane	0.954
Upper anterior facial height	0.901
Facial height ratio	0.986
UI maxillary plane	0.981
LI mandibular plane	0.935
Inter incisor angle	0.996
Naso labial angle	0.988
Lower lip to e line	0.974
Upper lip to e line	0.952
Lower anterior facial height	0.999

r value ranges between (0.935-0.999).

Hence it can be seen that the minor errors found in the study between the smartphone application tracing and manual tracing could be because of the difference in identification of the points and the use of lead pencil in the manual tracing method the width of which could vary the lines drawn and hence lead to errors. Also the smartphone application in the digital era is much reliable and convenient for the orthodontist. The smartphone application is pocket friendly and can be used anytime without the hassle of conventional view box and the various equipment's used for manual tracing. However initially using the touch gesture on the smartphone application requires some time to adapt but frequent use makes it much more easy and convenient.

Conclusion

With respect to the data obtained from the present study the null hypothesis cannot be rejected. Hence it can be concluded that:

1. Smartphone application based cephalometric analysis shows good agreement with manual tracing.
2. Smartphone application based cephalometric analysis can be used for clinical decision making.

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None.

Conflicts of interest

The author declares there are no conflicts of interest.

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