Original Article

Comparison of reproducibility of cephalometric measurements derived from handheld (smartphone) device application versus manual cephalometric tracing

ABSTRACT

Objective: The objective of this study is to assess the reproducibility of cephalometric measurements derived from an application designed for handheld (smartphone) devices and manual cephalometry.

Materials and Methods: Thirty pretreatment lateral cephalograms obtained from the same digital cephalostat were analyzed. Tracings were done using CephNinja for iPhone (Cyncronus) and manually by the hand on acetate sheets. Cephalometric landmarks and angular and linear measurements were recorded. All tracings were performed by the same investigator.

Statistical Analysis: To evaluate reproducibility, for each cephalometric measurement, the agreement between the value derived from CephNinja, and that measured manually was assessed with the intraclass correlation coefficient (ICC). Agreement was rated as low for an ICC <0.75 and an ICC >0.75 was considered indicative of good agreement. Furthermore, differences in measurements between those derived from CephNinja application and manual tracing were statistically evaluated ($P < 0.05$).

Results: All the measurements had ICC >0.75, indicating high agreement among both the tracing methods. Differences in measurements between CephNinja and hand tracing were not statistically significant for any of the cephalometric parameters.

Conclusion(s): Handheld (smartphone)-assisted cephalometric analysis shows good agreement with manual tracing and can be employed for clinical decision-making.

Keywords: Automation, Cephalometric analysis, Digital Cephalometric Analysis, smartphone orthodontic application

INTRODUCTION

Lateral cephalometric analysis has gained wide acceptance in orthodontics owing to its application in the determination of orthodontic diagnosis, treatment planning, and research.

Cephalometric radiology too has evolved from its humble beginning as film-based cephalometry as introduced by Hofrath[1] and Broadbent.[2] Digital cephalometry in its recent avatar employs a digital image, acquired directly from a digital cephalostat. This digital image is then imported into specially designed cephalometric softwares; using these softwares, various cephalometric analyses are performed. Digital cephalometric analysis offers several advantages over the earlier system of performing manual cephalometric analysis such as ease and efficiency of performing cephalometric analysis.[3-6] The operator is required to correctly identify the cephalometric points required, the software can then compute as many analysis as the operator desires. This helps in reducing the error in reporting various linear

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and angular values due to the elimination of human error over conventional manual tracing.[7,8] In addition, digital cephalometry aids in efficient archiving and retrieval of cephalometric films.[9]

However, in order to use such software, the operator has to acquire a desktop/workstation, which severely compromises his/her mobility. "Convergence" being the key these days, most technologies are integrating various aspects of work to as few devices as possible. The use of a portable hand-held device, especially a smartphone, which already has applications designed for practice management, patient education, patient data archiving, and retrieval seems to be the order of the day. Hence, the introduction of an application, especially designed for a smartphone to perform cephalometric analysis seems logical. However, any new application in this field must first be verified for accuracy against manually traced cephalometric methods.

With this objective in mind, the present study was conducted to assess the reproducibility of cephalometric measurements derived from a handheld (smartphone) device-based application as compared to manual tracings. This study was similar to an investigation by Goracci and Ferrari in 2014, they evaluated a different application using a tablet device.[10]

The null hypothesis established was that there is no statistically significant difference between linear and angular measurements derived from a handheld (smartphone)-based application as compared to those obtained from manual cephalometric tracing.

MATERIALS AND METHODS

Pretreatment lateral cephalometric radiographs of 30 patients were acquired using the same digital cephalostat (Carestream Kodak 8000, Carestream Health Inc., NY, USA). The participants were positioned in the natural head position while obtaining the cephalogram. The image magnification according to the radiological machine manufacturer is 1.14. There was no discrimination in subject selection with respect to gender, type of malocclusion, or skeletal pattern.

The exclusion criteria were as follows: Cephalograms with missing posterior teeth, low-quality images, or images with artifacts that would hinder the accurate identification of skeletal structures and cephalometric points.

Handheld (smartphone)-assisted digital tracing was done using CephNinja version 3.31 (Cyncronus; free download from Apple App Store) on an iPhone 6 (Apple Corporation, Palo Alto, CA, USA). Before tracings, the cephalograms were calibrated using the tools within the application. Landmark identification was done using touch gesture on the iPhone.

Manual tracings employed the same radiographs printed on film using the Kodak Digital Imaging software and were printed at the same magnification. The tracings were performed on clear acetate sheets affixed to the cephalogram film and using a 2H pencil, 15 cm scale and protractor. Bilateral structures were averaged to a single landmark.

All tracings (manual and digital) were done by the same investigator, an orthodontist with extensive experience in cephalometrics. Dental and skeletal landmarks employed in Steiner's analysis[11] were identified. In order to accurately identify the dental structures, namely maxillary and mandibular central incisors the following points were points were digitized: For maxillary central incisor (U1), tip of the crown of the upper central incisor maxillary central incisor and apex of the root of the upper central incisor, whereas for mandibular central incisor tip (L1), tip of the crown of the lower central incisor and mandibular lower incisor apex. Figure 1 is a screenshot of the user interface of CephNinja application with all landmarks located.

To assess intraoperator error, all cephalograms were re-traced by the same investigator by both the methods. All re-tracings were done 3 weeks after the first tracings.

Statistical analysis

To determine intrarater reliability between manual and digital tracing techniques, the intraclass correlation co-efficient (ICC) of repeated measurements was calculated for every cephalometric variable.[10] To evaluate the reproducibility for each cephalometric parameter, the

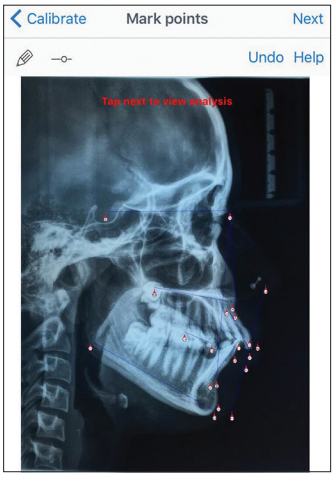

Figure 1: Screenshot of the user interface of CephNinja application with all landmarks located

agreement between the value derived from CephNinja application and that measured manually was assessed with ICC. Agreement was rated as low for ICC lower than 0.75. However, if the ICC was >0.75, it indicated good agreement. Differences in measurements between application based and manual tracings were subjected to *t*-test for the independent samples. The level of statistical significance was set at $P < 0.05$. The statistical analysis was performed using the Statistical Package for the Social Sciences software version 11.0 (SPSS Inc., Chicago, IL, USA) on a Windows operating system platform (Microsoft Corporation, Redmond, USA).

RESULTS

From Table 1, it can be observed that ICC values calculated for repeated measurements with each tracing technique indicate high inter-rater reliability. The ICC values of cephalometric measurements recorded with both the tracing techniques are given in Table 2. All cephalometric values have an ICC >0.75 (ICC >0.75) indicating high agreement between both the tracing techniques. The highest values of ICC were recorded for SNA and SNB.

Table 3 contains the data regarding mean and standard deviations of the differences in the measurements between handheld (smartphone)-assisted tracing and manual tracing. The *t*-test revealed that for all parameters, there were statistically similar amounts of difference between handheld (smartphone)-assisted tracing and manual tracing.

DISCUSSION

Based on the results of the statistical analysis, the null hypothesis cannot be rejected. All values have reported an ICC >0.75, indicating the high degree of reproducibility of cephalometric analysis conducted manually or using the application. The lack of statistical significance of the differences in the measurements between both methods supports the evidence that handheld (smartphone)-assisted cephalometric analysis can be reliably used in the orthodontic diagnosis.

Digital cephalometry offers various advantages over manual cephalometry such as ease of use and efficiency in reducing time spent otherwise on manual tracing. The CephNinja application adds to these advantages with user friendliness and portability. CephNinja application 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.[12]

The inferences of this investigation are very similar to those reported in a previous study.[10] Thus conclusively reinforcing the fact that tablet and/or handheld (smartphone)-assisted cephalometric analysis are reliable and can be used for clinical decision-making.

Table 1: Intraclass correlation coefficients of repeated cephalometric measurements in handheld (smartphone) assisted, and manual tracing groups for assessing intrarater reliability

Parameters	ICC for CephNinja	ICC for Manual Tracing
SNA	0.889	0.912
SNB	0.943	0.937
ANB	0.915	0.941
SN/Go-Gn	0.786	0.896
U1 to NA (a)	0.821	0.837
L1 to NB (a)	0.832	0.829
U1/L1	0.847	0.836
U1 to NA (l)	0.785	0.793
L1 to NB (l)	0.798	0.799

ICC: Intraclass correlation coefficient (ICC > 0.075)

Table 2: Intraclass correlation coefficients of cephalometric measurements derived from handheld (smartphone) assisted and manual tracing for assessing reproducibility

Parameters	ICC
SNA	0.862
SNB	0.854
ANB	0.812
SN/Go-Gn	0.796
U1 to NA (a)	0.724
L1 to NB (a)	0.731
U1/L1	0.825
U1 to NA (l)	0.781
L1 to NB (l)	0.763

ICC: Intraclass correlation coefficient (ICC > 0.075)

Table 3: Differences in cephalometric measurements of parameters between those derived from CephNinja application and manual tracing

Parameter	CephNinja versus manual tracing	*P*
SNA	0.47±0.41	0.53
SNB	0.41±0.52	0.49
ANB	0.02±0.36	0.61
SN/Go-Gn	0.03±0.39	0.37
U1 to NA (a)	0.45±0.61	0.45
L1 to NB (a)	0.36±0.42	0.19
U1/L1	0.32±0.45	0.23
U1 to NA (l)	0.04±0.56	0.34
L1 to NB (l)	0.03±0.39	0.15

*Mean + Standard Deviation, The level of statistical significance was set at $P<0.05$

In the present study, a single investigator traced all the cephalograms. This was done to avoid the errors caused by inter-examiner variation as reported in a previous study.[13] Steiner's analysis was chosen because the landmarks/points used in it are easy to locate. All these landmarks are easily reproducible.

However, gaining proficiency in using the touch gesture for landmark identification requires time to adapt. Furthermore, the accuracy while locating points using a touch gesture needs to be investigated in a larger sample. We recommend conducting similar studies using larger sample sizes and comparing more applications which can be run on hand-held portable devices.

CONCLUSION(S)

With respect to the data obtained from the present study, it can be concluded that:

- Handheld (smartphone)-assisted cephalometric analysis shows good agreement with manual tracing
- Handheld (smartphone)-assisted cephalometric analysis can be used for clinical decision-making
- Handheld (smartphone)-assisted cephalometric analysis has the added advantage of ease of use and portability when compared to other cephalometric analysis techniques.

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Conflicts of interest

There are no conflicts of interest.

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