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Validity and Reliability of the Cephninjapro Application Versus the Dolphin Software for Linear and Angular Cephalometric Measurements

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Abstract

Aim: Cephalometric analysis is a main part of diagnostics in orthodontics. Modern cephalometric analysis methods include using digital software or mobile applications. This study aimed to assess the validity and reliability of the CephNinjaPro application for linear and angular cephalometric measurements.
Methods: In this cross-sectional study, 30 randomly selected lateral cephalograms were digitized by a digital scanner. The required landmarks for five linear and eight angular measurements were identified on all cephalograms using a fine tip pen by an experienced orthodontist, and then rescanned. To assess the validity of manual versus digital landmark identification using the CephNinjaPro application, the landmarks were identified on scanned cephalograms in both the CephNinjaPro application and Dolphin software. The results were compared before and after landmark identification. The results of the Dolphin software and the CephNinjaPro application were also compared before and after landmark identification. Data were analyzed using the paired t-test and Wilcoxon test.
Results: The results showed significant differences in the angles SNA ($P<0.001$), SNB ($P<0.001$), inter-incisal ($P=0.001$), and MP-SN ($P<0.001$), and the Ga ($P<0.001$) between the Dolphin software and CephNinjaPro application before landmark identification. Also, significant differences were observed in the Ga ($P<0.001$) and SN-MP ($P<0.001$) angle between the Dolphin software and CephNinjaPro application after landmark identification.
Conclusion: The CephNinjaPro application has acceptable validity and reliability for most of the linear and angular cephalometric measurements from the clinical perspective. Nonetheless, interpretation of results regarding some measurements should be done with caution.

Keywords: Linear measurements; Angular measurements; Cephalometric analysis.

1. Background

Cephalometric analysis is commonly performed in orthodontics for diagnosis, treatment planning, assessment of treatment results, and prediction of growth and development. It also provides valuable information about the craniofacial morphology, facial growth pattern, craniofacial dimensions, and skeletal, or dentoalveolar abnormalities (1). Although three-dimensional cephalometric methods exist, two-dimensional cephalograms remain a gold standard for diagnostic purposes in orthodontic patients due to its availability and lower cost (1). Nonetheless, anatomical hard and soft tissue variations, the quality of the cephalogram, and experience of the clinician can all affect the accuracy of landmark identification and lead to errors (2).

Technical advances in computer science, however, now enable the tracing of cephalograms by using digitizers, or direct tracing on digital images displayed on the screen (3). Two approaches used for cephalometric analysis are the manual approach and the computer-aided approach, in which landmarks could be recognized manually or digitally on screen or automatically by the computer. Subsequently, the computer software program automatically measures the distances and angles to accomplish cephalometric analysis (4).

Manual analysis of a cephalogram by a ruler and a protractor is time-consuming and can significantly increase the rate of errors. On the other hand, the introduction of computerized cephalometric analysis enables direct digitization of radiographs. This process is more rapid, decreases errors due to automatic measurements, and facilitates data transfer between dental professionals (2).

Errors in cephalometric analysis can be categorized as systematic errors and random errors. Random errors are related to tracing, landmark identification, and measurements. Mechanical errors are related to drawing lines between the identified landmarks and errors in measurements made by a protractor that can be prevented by computer-aided cephalometric analysis. Also, the measurement errors in computer-aided analysis are not higher than that of hand tracing, if the landmarks are identified manually. However, variations in landmark identification are still a main cause of random errors in digital cephalometry (5).

OrthoCeph, Dolphin, Ax. Ceph and Faca are the available specialized software programs commonly used for cephalometric analysis. These software programs can greatly help orthodontists in cephalometric analysis for the purpose of diagnosis and treatment planning (4). CephNinjaPro is a mobile application for cephalometric analysis that can be downloaded and installed on smartphones with android and IOS operating systems (1). It has several features including cephalometric analysis by using the Burstone, McNamara, Steiner, Wits, Jarabak, Down and Tweed's analyses. It also enables landmark identification using one's finger that is placed on the cell phone screen (6). Furthermore, the reliability and validity of Dolphin software for cephalometric analysis has been previously confirmed, and it currently serves as the gold standard for the comparison of relevant software programs and smartphone applications (7-13).

Considering the significance of cephalometric analysis, and the novelty of the application CephNinjaPro, this study aimed to assess the validity and reliability of the CephNinjaPro application for linear and angular cephalometric measurements.

2. Methods

This cross-sectional study was conducted on lateral cephalograms of patients that were randomly selected from the archives of an orthodontic office in Zanjan, Iran, during the period of January to March 2019. The sample size was calculated to be 25 considering the confidence level of 95% with a 20% margin of error according to similar previous studies (1-3); thus, 30 lateral cepalagrams were included in the study. The Instructional Review Board number of the ethics committee of the Zanjan University of Medical Sciences is IR.ZUMS.REC.1398.45. An Informed consent was obtained from all the subjects whose documents were evaluated in the study, and privacy of the records were maintained strictly by the researchers.

The inclusion criteria were

- good-quality radiographs
- permanent dentition
- lateral cephalograms that were obtained in the natural head position

The exclusion criteria were

- artifacts in radiographs interfering with anatomical landmarks
- presence of impacted or missing teeth
- craniofacial deformity or asymmetry
- excess soft tissue (as determined on radiographs) that could interfere with anatomical landmark identification
- Presence of supernumerary teeth that interfere with landmark recognition

Assessment of the validity of the CephNinjaPro application

All lateral cephalograms were first scanned by a digital scanner (ScanMaker i800; MICROTEK) in order for the output data of both the Dolphin software and CephNinjaPro application to be the same. Next, 21 anatomical landmarks were marked on each radiograph with a fine point red marker, and they were then scanned with the same scanner. To assess the accuracy of landmark identification on the cell phone display monitor versus the computer monitor, both groups of radiographs (raw and pre-marked) were imported into the CephNinjaPro application (version 3.62) on an iPhone 6S and the Dolphin Imaging Software was imported into a personal computer (Fig. 1). For pre-marked radiographs, new points were marked on the specified points.

Five linear and eight angular measurements were calculated in both programs. All measurements were made by the same examiner who was an experienced orthodontist. A ruler was used to calibrate each cephalogram. In both cephalometric analysis programs, the observer could adjust the brightness, contrast, magnification, and zoom in/out. The 21 identified anatomical landmarks and their definitions were as follows:

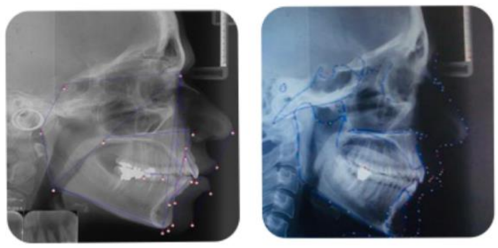

Figure 1. Screenshot of the user interface of the CephNinjaPro application (left) and Dolphin Software (right)

1. Sella (S): The geometric center of sella turcica
2. Nasion (N): The most anterior point of the frontonasal suture in the midsagittal plane
3. Point A (subspinale): The most posterior midline point on the premaxilla between the prosthion and the anterior nasal spine
4. Point B (supramentale): The most posterior midline point in the concavity of the mandible between the infradentale and pogonion
5. Gonion (Go): A point on the angle of the mandible at the bisection of the *angle* formed by the line tangent to the inferior border of the mandible and the line tangent to the posterior border of the ramus. If a double border was presence, the most posterior and inferior borders were assumed as reference lines, respectively.
6. Menton (Mn): The most inferior point of the mandibular symphysis
7. Gnathion (Gn): The midpoint between the pogonion and menton
8. Pogonion (Pog): The most anterior point of the chin
9. Apex of the upper incisor: Tip of the maxillary central incisor root
10. Edge of the upper incisor: The incisal edge of the maxillary central incisor
11. Apex of the lower incisor: Tip of the mandibular central incisor root
12. Edge of the lower incisor: The incisal edge of the mandibular central incisor
13. Articulare (Ar): The point at the intersection of the posterior ramus and the inferior part of the posterior cranial base (occipital bone)
14. Pogonion' (Pog'): The most prominent or most anterior point of the chin soft tissue in the midsagittal plane
15. Pronasale (Pn): The most prominent or most anterior point of the nose (nose tip)
16. Labrale superius (LS): The most anterior point on the upper lip lying on the median sagittal plane on a line drawn across the boundary of the vermilion border and skin
17. Labrale inferius (LI): The median point in the lower margin of the lower membranous lip
18. Point A: Perpendicular to the occlusal plane
19. Point B: Perpendicular to the occlusal plane
20. Occlusal contact point in the premolar region: Occlusal contact at the site of premolar teeth
21. Occlusal contact point in the molar region: Occlusal contact at the site of molar teeth (14).
22. The linear and angular measurements were as follows (1-3):
23. SNA: Angle formed between S-N and N-A (Steiner's analysis)
24. SNB: Angle formed between S-N and N-B (Steiner's analysis)
25. ANB: Angle formed between A-N and N-B (Steiner's analysis)
26. Mandibular plane to SN: Angle formed between the SN plane and the mandibular plane (Steiner's analysis)
27. Inter-incisal angle: Angle formed between the lower and upper incisors (composite dental analysis)
28. Saddle angle: Angle formed between N, S, and Ar points (Jarabak's analysis)
29. Articular angle: Angle formed between S, Ar, and Go points (Jarabak's analysis)
30. Gonial angle (Ga): Angle formed between Ar, Go, and Gn points (Jarabak's analysis)
31. U1-A distance: Distance between the facial surface of the upper incisor and a vertical line drawn through point A (McNamara's analysis)
32. L1-A distance: Distance between the incisal edge of the lower incisor and a line drawn from point A-pog (McNamara's analysis)
33. Upper lip/E-line: Vertical distance from the upper lip point to the E line (composite soft tissue analysis)
34. Lower lip/E-line: Vertical distance from the lower lip point to the E line (composite soft tissue analysis)
35. Wits: Linear distance between points A and B parallel to the occlusal plane (Wits appraisal)

Assessment of the reliability of the CephNinjaPro application

To assess intra-examiner reliability, 10 randomly selected lateral cephalograms underwent linear and angular measurements manually with the CephNinjaPro application and Dolphin software by the examiner two weeks after the primary measurements, respectively. The intraclass correlation coefficient (ICC) was calculated. The ICC values <0.8 indicated poor agreement while values >0.8 indicated good agreement (15).

Statistical analysis

Data were analyzed using the software SPSS version 24. The data obtained from the Dolphin software and CephNinjaPro application were compared by the paired t-test in case of normal distribution, and the Wilcoxon test for non-normal distribution. The level of significance was set at 0.05.

3. Results

Table 1 presents the linear and angular measurements made with the Dolphin software before and after landmark identification. As shown, of all the measured parameters SNA (P<0.001), SNB (P<0.001), Art (P=0.036) and Ga (P<0.001) showed a significant difference before and after landmark identification with the Dolphin software.

Table 2 presents the linear and angular measurements made in the CephNinjaPro application before and after landmark identification. As shown, of all the measured parameters SNA (P=0.040), SNB (P=0.023), UL-E. line (P=0.050), and Ga (P=0.017) showed a significant difference before and after landmark identification with the CephNinjaPro application.

Table 3 compares the linear and angular measurements in the Dolphin software and the CephNinjaPro application before landmark identification. The results showed significant differences in the angles SNA (P<0.001), SNB (P<0.001), inter-incisal (P=0.001), MP-SN (P<0.001) and Ga (P<0.001) when the Dolphin software was compared with the CephNinjaPro application before landmark identification.

Table 1. Linear and angular measurements made in the Dolphin software before and after landmark identification

Variable	Status	Mean±SD	P-value	Normality Test Result
SNA (degree)	Before	40/3±04/81	<0.001	0.2
	After	3.29±82.12		0.2
SNB (degree)	Before	3.60±76.39	<0.001	0.2
	After	3.37±77.57		0.2
ANB (degree)	Before	1.86±4.66	0.650	0.2
	After	1.59±4.54		0.2
Saddle angle (degree)	Before	6.16±124.88	0.812	0.1
	After	6.65±124.70		0.049
Art. Angle (degree)	Before	8.41±147.79	0.036	0.2
	After	8.19±144.46		0.2
Ga (degree)	Before	8.44±115.36	<0.001	0.2
	After	8.70±119.59		0.2
Inter-incisal angle (degree)	Before	10.56±125.44	0.32	0.2
	After	9.86±127.39		0.2
MP-SN angle (degree)	Before	7.56±34.70	0.584	0.2
	After	6.40±34.49		0.1
U1-NA (mm)	Before	4.21±7.32	0.876	0.2
	After	4.22±7.21		0.2
L1-N-Pog (mm)	Before	4.26±7.02	0.439	0.2
	After	4.85±7.38		0.2
UL-E. line (mm)	Before	4.38±8.03	0.247	0.1
	After	4.39±8.64		0.007
LL-E. line (mm)	Before	3.64±5.01	0.434	0.2
	After	3.69±5.27		0.2
Wits (mm)	Before	4.57±6.17	0.118	0.2
	After	4.41±5.13		0.001

SNA, Sella-Nasion-A point angle; SNB, Sella-Nasion-B point angle; ANB, A point-Nasion-B point angle; Art, Articular; Ga; Gonial angle; MP-SN, Mandibular plan to Sella-Nasion angle; U1-NA, Upper incisor incisal edge distance to Nasion-A point line; L1-N-Pog, Lower incisor incisal edge to Nasion-Pogonion line; UL-E line, Upper lip to E-line distance; LL-E line, Lower lip to E-line distance; SD: Standard deviation

Table 2. Linear and angular measurements made in CephNinjaPro application before and after landmark identification

Variable	Status	Mean± SD	P value	Normality test result
SNA (degree)	Before	3.04±82.67	0.040	0.2
	After	3.24±82.07		0.2
SNB (degree)	Before	3.04±78.04	0.023	0.2
	After	3.37±77.50		0.2
ANB (degree)	Before	1.70±4.62	0.770	0.2
	After	1.61±4.56		0.2
Saddle angle (degree)	Before	6.09±124.09	0.331	0.2
	After	6.66±124.75		0.2
Art. Angle (degree)	Before	5.75±145.54	0.962	0.2
	After	5.97±145.58		0.1
Ga (degree)	Before	5.96±125.17	0.017	0.2
	After	6.53±123.97		0.2
Inter-incisal angle (degree)	Before	11.53±129.70	0.34	0.2
	After	9.95±127.94		0.2
MP-SN angle (degree)	Before	6.05±32.24	0.252	0.2
	After	6.71±31.74		0.2
U1-NA (mm)	Before	2.16±3.32	0.748	0.1
	After	2.06±3.25		0.1
L1-N-Pog (mm)	Before	2.17±3.65	0.933	0.2
	After	2.28±3.66		0.2
UL-E. line (mm)	Before	2.11±4.02	0.050	0.1
	After	2.16±4.23		0.07
LL-E. line (mm)	Before	1.77±2.46	0.551	0.2
	After	1.86±2.53		0.041
Wits (mm)	Before	2.42±3.32	0.739	0.2
	After	2.17±3.20		0.2

SNA, Sella-Nasion-A point angle; SNB, Sella-Nasion-B point angle; ANB, A point-Nasion-B point angle; Art, Articular; Ga; Gonial angle; MP-SN, Mandibular plan to Sella-Nasion angle; U1-NA, Upper incisor incisal edge distance to Nasion-A point line; L1-N-Pog, Lower incisor incisal edge to Nasion-Pogonion line; UL-E line, Upper lip to E-line distance; LL-E line, Lower lip to E-line distance; SD: Standard deviation

Table 3. Comparison of the linear and angular measurements in the Dolphin software and CephNinjaPro application before landmark identification

Variable	Status	Mean±SD	P-value	Normality Test Result
SNA (degree)	Dolphin	3.40±81.04	<0.001	0.2
	CephNinjaPro	3.04±82.67		0.2
SNB (degree)	Dolphin	3.60±76.39	<0.001	0.2
	CephNinjaPro	3.04±78.04		0.2
ANB (degree)	Dolphin	1.86±4.66	0.853	0.2
	CephNinjaPro	1.70±4.62		0.2
Saddle angle (degree)	Dolphin	6.16±124.88	0.397	0.1
	CephNinjaPro	6.09±124.09		0.2
Art. Angle (degree)	Dolphin	8.41±147.79	0.147	0.2
	CephNinjaPro	5.75±145.54		0.2
Ga (degree)	Dolphin	8.44±115.36	<0.001	0.2
	CephNinjaPro	5.96±125.17		0.2
Inter-incisal angle (degree)	Dolphin	10.56±125.44	0.001	0.2
	CephNinjaPro	11.53±129.70		0.2

MP-SN angle (degree)	Dolphin	7.56±34.70	<0.001	0.2
	CephNinjaPro	6.05±32.24		0.2

Table 3. Continued

U1-NA (mm)	Dolphin	4.21±7.32	0.398	0.2
	CephNinjaPro	4.32±6.64		0.1
L1-N-Pog (mm)	Dolphin	4.26±7.02	0.443	0.2
	CephNinjaPro	4.34±7.30		0.2
UL-E. line (mm)	Dolphin	4.38±8.03	0.230	0.1
	CephNinjaPro	4.22±8.04		0.1
LL-E. line (mm)	Dolphin	3.64±5.01	0.132	0.2
	CephNinjaPro	3.54±4.92		0.2
Wits (mm)	Dolphin	4.57±6.17	0.289	0.2
	CephNinjaPro	4.84±6.64		0.2

SNA, Sella-Nasion-A point angle; SNB, Sella-Nasion-B point angle; ANB, A point-Nasion-B point angle; Art, Articular; Ga; Gonial angle; MP-SN, Mandibular plan to Sella-Nasion angle; U1-NA, Upper incisor incisal edge distance to Nasion-A point line; L1-N-Pog, Lower incisor incisal edge to Nasion-Pogonion line; UL-E line, Upper lip to E-line distance; LL-E line, Lower lip to E-line distance; SD: Standard deviation

Table 4 compares the linear and angular measurements in the Dolphin software and CephNinjaPro application after landmark identification. According to the results, significant differences existed in the Ga (P<0.001) and MP-SN (P<0.001) angles when the Dolphin software was compared to the CephNinjaPro application after landmark identification. Table 5 presents the ICC

Table 4. Comparison of the linear and angular measurements in the Dolphin software and CephNinjaPro application after landmark identification

Variable	Status	Mean±SD	P-value	Normality Test Result
SNA (degree)	Dolphin	12.29±82.3	530.0	2.0
	CephNinjaPro	07.24±82.3		2.0
SNB (degree)	Dolphin	57.37±77.3	476.0	2.0
	CephNinjaPro	50.37±77.3		2.0
ANB (degree)	Dolphin	54.59±4.1	746.0	2.0
	CephNinjaPro	56.61±4.1		2.0
Saddle angle (degree)	Dolphin	70.65±124.6	706.0	049.0
	CephNinjaPro	75.66±124.6		2.0
Art. Angle (degree)	Dolphin	46.19±144.8	084.0	2.0
	CephNinjaPro	58.97±145.5		1.0
Ga (degree)	Dolphin	59.70±119.8	<0.001	2.0
	CephNinjaPro	97.53±123.6		2.0
Inter-incisal angle (degree)	Dolphin	39.86±127.9	141.0	2.0
	CephNinjaPro	94.95±127.9		2.0
MP-SN angle (degree)	Dolphin	49.40±34.6	<0.001	1.0
	CephNinjaPro	74.71±31.6		2.0
U1-NA (mm)	Dolphin	21.22±7.4	324.0	2.0
	CephNinjaPro	50.12±6.4		1.0
L1-N-Pog (mm)	Dolphin	38.85±7.4	245.0	2.0
	CephNinjaPro	32.28±7.4		2.0
UL-E. line (mm)	Dolphin	64.39±8.4	130.0	007.0
	CephNinjaPro	36.32±8.4		07.0
LL-E. line (mm)	Dolphin	27.69±5.3	430.0	2.0
	CephNinjaPro	06.72±5.3		041.0
Wits (mm)	Dolphin	13.41±5.4	540.0	001.0
	CephNinjaPro	40.34±6.4		2.0

SNA, Sella-Nasion-A point angle; SNB, Sella-Nasion-B point angle; ANB, A point-Nasion-B point angle; Art, Articular; Ga; Gonial angle; MP-SN, Mandibular plan to Sella-Nasion angle; U1-NA, Upper incisor incisal edge distance to Nasion-A point line; L1-N-Pog, Lower incisor incisal edge to Nasion-Pogonion line; UL-E line, Upper lip to E-line distance; LL-E line, Lower lip to E-line distance; SD: Standard deviation.

Table 5. ICC values calculated to assess the reliability of measurements in three groups: Manual, CephNinjaPro, Dolphin

	ICC of linear measurements in Manual landmark identification group	ICC of angular measurements in Manual landmark identification group	ICC of linear measurements after landmark identification in CephNinjaPro	ICC of angular measurements after landmark identification in CephNinjaPro	ICC of linear measurements after landmark identification in Dolphin	ICC of angular measurements after landmark identification in Dolphin
Case 1	0.982	1	0.992	1	0.996	1
Case 2	0.990	1	0.980	1	1	1
Case 3	0.913	1	0.833	1	0.984	1
Case 4	0.986	0.998	0.833	0.998	0.883	1
Case 5	0.913	1	0.996	0.999	0.997	0.998
Case 6	1	0.999	0.986	1	1	1
Case 7	0.982	1	0.980	0.999	0.986	0.996
Case 8	1	1	0.984	0.999	1	0.999
Case 9	0.958	0.999	0.884	1	0.876	1
Case 10	0.988	0.999	0.833	0.997	0.999	0.998

ICC, Intraclass Correlation Coefficient

values calculated to assess the reliability of measurements. The range of ICC for different measurements was 0.883-1, which shows an excellent reliability of measurements.

4. Discussion

This study assessed the validity and reliability of the CephNinjaPro application for linear and angular cephalometric measurements. The results showed a reliability of >0.8, which indicates the excellent reliability of the measurements made by the examiner (15). For assessment of the validity of manual and digital landmark identification with the CephNinjaPro application and the Dolphin software, the pre-marked films were used and the same points were marked again on the application or software environment. By doing so, the location of landmarks was predefined for the application and software in order not to be affected by the zoom in/out process, and to minimize the visual and diagnostic errors. Although the accuracy of computerized and manual cephalometric analysis has been compared in many previous studies (3,10-12), this study was unique in that it compared the accuracy of anatomical landmark identification on a cell phone using the CephNinjaPro application in comparison with landmark identification on a personal computer with the Dolphin software. The selection of the Dolphin software for the purpose of comparison in this study was due to the fact that its optimal validity and reliability have been previously confirmed in many studies and it is currently used as the gold standard to assess the validity of other cephalometric software programs and applications (7-13).

In the present study, the comparison of the results of the Dolphin software before and after landmark identification revealed no significant difference in any parameter except for the SNA, SNB, Ga, and Art. Despite being statistically significant, this difference was 1° for the SNA and SNB, which is considered acceptable from the clinical perspective according to Livas et al. (16) According to Sekiguchi and Savara (17), identification of the Na may be difficult especially when the nasofrontal suture cannot be clearly identified. Since Na was used to measure the SNA and SNB angles in our study, this statement may explain the significant difference in this respect. For the Art and Ga angles, the difference was >3° and 4°, which was statistically and clinically significant. Since the measurement of both angles requires the identification of the Go point, it may be the source of error. Errors in identification of the Go point can be related to incorrect head position during imaging. Also, in general, the Go point cannot be easily and clearly identified on all cephalograms (16).

Comparison of the results of the CephNinjaPro application before and after landmark identification in the present study revealed significant differences only in the SNA, SNB, and Ga angles and UL-E line. The difference in the SNA and

SNB angles was <1°, and therefore it was not clinically significant. The difference in the Ga angle was 2.8°, which can be due to improper head positioning of patients, double angle, and usually because of the difficulty in identifying the Go point (16). The difference in the UL-E line was <0.21 mm, which was not clinically significant (16).

A comparison of the Dolphin software and CephNinjaPro application before landmark identification revealed significant differences in the SNA, SNB, Ga, MP-SN, and inter-incisal angles. The difference in the SNA and SNB angles was not significant considering clinical use. The difference in the Ga angle can be due to the aforementioned factors (16). The difference in the inter-incisal angle can be due to the difficulty in identifying related points, including the apex and incisal edge of the upper and lower incisors, because of several superimpositions, especially in the maxilla, complicate correct identification of these points. Livas et al. (16) evaluated the validity and reliability of cephalometric analysis performed by OneCeph and CephNinjaPro smartphone applications in comparison with the ViewBox software program as the gold standard. They reported variations in identification of some points such as the lower incisor apex. Difficulty in identifying this point could be due to the significant difference in the calculation of the interincisal angle in the present study. Paixão et al. (18) evaluated the differences in manual tracing and digital tracing with the Dolphin software and reported significant differences in measurements related to upper and lower incisors due to difficulty in tracing dental structures in the maxilla and mandible. Their results were in agreement with our findings regarding significant difference in the calculation of the interincisal angle. Sayar and Kilinc (15) compared digital tracings obtained with the CephNinjaPro application with manual tracings and concluded that errors related to the measurements of the mandibular incisor axis were correlated with the sensitivity of the display monitor of the tracing application, because when searching for this point, excessive zoom-in is performed, which causes errors. The same error was observed in the present study.

In this study, the difference in the MP-SN angle was around 2°, which was not clinically significant. This difference may be attributed to the difficulty in identifying the mandibular plane due to variations in the Go angle (16).

A comparison of the results of the Dolphin software and CephNinjaPro application after landmark identification in this study revealed a significant difference only in the Ga and MP-SN angles. The reduction of significant differences in this mode was due to the fact that the points were pre-defined for both the application and software program. The difference in the Ga angle was 8° and clinically significant. This value was 3° for the MP-SN angle, which was clinically significant as well. Such differences may be due to the difficulty in identifying the Go and N points, as explained earlier (16-17).

Strength and limitations

Repetition of measurements and evaluation of a high number of commonly used landmarks were the strengths of this study. Also, one examiner analyzed the results because the aim was to assess the reliability of the CephNinjaPro application and several examiners could affect the results due to their variations in the level of expertise and knowledge in using the application and in landmark identification.

On the other hand, we compared only a limited number of linear and angular cephalometric measurements on a limited number of cephalograms, which may affect the external validity of the results. Therefore, we suggest further studies that include a larger sample size and greater number of measurements.

Conclusion

In conclusion, the CephNinjaPro application has acceptable validity and reliability for linear and angular cephalometric measurements. Nonetheless, the interpretation of results regarding some angular measurements should be done with caution.

Future studies are required to assess the performance of newer versions of cephalometric analysis applications that are also suitable for use on tablets. Tablets have all the advantages of smartphones plus a larger display monitor, which may enhance landmark identification. Also, future studies are recommended to assess and compare the accuracy of landmark identification with a computer mouse and finger on touchscreen monitors.

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