

A comparison of cephalometric measurements obtained using conventional and digital methods

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(Index words: cephalometric analysis, digital cephalometry, conventional cephalometry, land mark identification)

Abstract

Introduction Cephalometry is a radiologic modality used in orthodontics that may play a significant role in clarifying doubtful situations where clinical assessment alone is not adequate to arrive at a definite diagnosis.

Objectives The aim of the study was to explore the landmarks identification and compare the validity of skeletal, dental and soft tissue analysis obtained from the digital and conventional methods.

Method Sixty five digital radiographs were selected randomly from the orthodontic patient's records and 22 soft tissue and hard tissue land marks were identified by the single clinician. Five dental, five skeletal and two soft tissue parameters were assessed with 4 linear and 8 angular measurements were assessed manually and digitally with Nemoceph version 06.

Results No significant difference in mean values of SNA, SNB, Occlusal - SN and GoGn to SN – plane angles, upper lip protrusion (UL-Sn – Pog) and lower lip protrusion (LL-Sn – Pog) in both manual and digital methods. Mean values of UI – NA and LI-NB were significantly deviating in manual and digital methods. Both UI to NA and LI to NB linear and angular measurements showed poor agreement (<0.90) between the two methods in the assessment of Concordance correlation coefficient. Most of the linear (0.945) and angular (0.917) measurements showed excellent and good intra examiner reliability except for the UI – NA linear measurement (0.775) according to the Cronbach's alpha value.

Conclusion The validity of linear and angular measurements with the Nemoceph version-6 software and with the conventional method is highly correlated except for the UI to NA and LI-NB measurements. These dento – alveolar measurements with lower validity should be reconsidered at the time of cephalometry analysis especially in relation to land mark identification.

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Introduction

Radiological investigations play a very important role in the diagnosis of clinical conditions and management of patients in medical and dental practice. Cephalometry is a radiological modality used in orthodontics that contributes significantly to clarify doubtful situations where clinical assessment alone is not adequate to arrive at a definite diagnosis. Particularly, cephalograms, by means of cephalometric analysis, used for diagnosis, treatment planning, monitoring treatment outcome and evaluation of growth and development of dental and craniofacial structures [1,2]. Therefore, it is important to get accurate measurements with the cephalometry analysis for the proper diagnosis and plan the treatment for orthodontic patients.

Cephalometric analysis can be performed by manual and/or computerized methods [2]. Manual method which is performed using a tracing paper on the radiograph is considered as the conventional and most frequently used method [1,2]. However, conventional cephalometric analysis has been identified to have several disadvantages including time consumption, erroneous hand tracing, difficulties in landmark identification and obtaining accurate measurements [3]. Inconsistent landmark identification is a particularly important source of error in conventional cephalometry and this error is specific to each anatomical landmark and is affected by the experience and training of observers [4]. Also, a loss of information in craniofacial biology, particularly occurring due to film deterioration has been observed as another significant drawback in conventional cephalometry [1,5]. Therefore, many clinicians have turned to use computers for diagnosis, treatment planning and growth prediction as well as to archive cephalograms digitally [5,6].

Rapid evolution of computer science and technology in the recent past has been the cause of considerable

impact on orthodontics generally and especially on cephalometry [7,8]. This rapid progress has led to the replacement of the manual tracing method by digital tracing [8,9]. As a result concerted effort has been applied to develop cephalometric software designed to yield data that would improve clinical decision making in orthodontic patient care. This has facilitated the availability of a wide array of analyses for lateral and antero-posterior computerized tracings [10]. Through these software cephalometric analyses have been made easier and time loss is minimized. This study aims to compare objectively the advantages and disadvantages, if any, between conventional and computer-aided cephalometric analyses and to determine which method provides accurate and best results for orthodontists [6]. Although several such studies have been reported in the literature, to our knowledge no such study has been so far reported from Sri Lanka. Considering the likely demographic differences and possible variations in the craniofacial characteristics of the Sri Lankan population it is deemed that this study is justifiable. Among the software which have become available for cephalometric analyses some such applications that have been subjected to comparative studies are Nemotec Digital Imaging Software [1], Dolphin Imaging Software [2,9], Vistadent [3] and Jiffy Orthodontic Evaluation (JOE) [3,6], Quick Ceph Image Pro [6], Nemoceph [8,10], including NemocephNx version [10].

The study conducted by Agarwal *et al.* on Nemotec Digital Imaging Software revealed that digital measurements obtained using the software were reproducible and comparable to the manual method for most of the variables [1]. The study carried out by Celik *et al.* on Vistadent 2.1 AT and JOE showed that computerized cephalometric measurements using direct digital imaging is preferable for its user friendly and time-saving characteristics [3]. The researches performed by Cavdar *et al* [6] using QuickCeph Image Pro and JOE and Kalra *et al* [8] using Nemoceph concluded that computerized analysis is reliable and advantageous with respect to time, archiving and enhancement of radiographs. A pilot study performed by Tanwani *et al* [9] using Dolphin Imaging Software version 11.7 discovered that manual and digital tracing methods show statistically significant difference. The study performed by Segura *et al* [10] on NemocephNx software revealed that this software shows excellent reliability for diagnosis using cephalometric digital radiography.

Only a single study has been reported in the literature to assess the accuracy and reliability of the software Nemoceph version 06 which is commonly used by the clinicians in Sri Lanka, in computerized cephalometric analysis [11]. Therefore, it was decided for the study to compare the cephalometric measurements using manual and digital methods.

Methods and materials

Sixty five lateral cephalograms were randomly selected from the records of patients attending the Division of Orthodontics, Faculty of Dental Sciences, University of Peradeniya. The soft copies of all lateral cephalograms which were taken by a single machine were transferred to Nemoceph cephalometric software program (Nemoceph, Version 6.0). The images were calibrated by identifying two crosshairs 10 mm apart. The image enhancement features of the software, such as brightness, contrast adjustment and magnification were used as needed to identify individual cephalometric landmarks as precisely as possible. Once all the 22 soft tissue and hard tissue landmarks (Figure 1) were marked, these landmarks were again adjusted and corrected for accurate measurements. Five dental, five skeletal and two soft tissue parameters were assessed with 4 linear and 8 angular measurements and all these measurements were automatically calculated by the tracing software.

The same 65 radiographs were traced with all the hard and soft tissue landmarks manually on tracing paper with 0.1 mm drawing pencil on tracing paper on a view box using transilluminated light. Same linear and angular measurements were analyzed to the nearest 0.5 mm and 0.5° respectively with the help of millimetre ruler and protractor. The principle investigator performed the manual assessment blinded to the digital method.

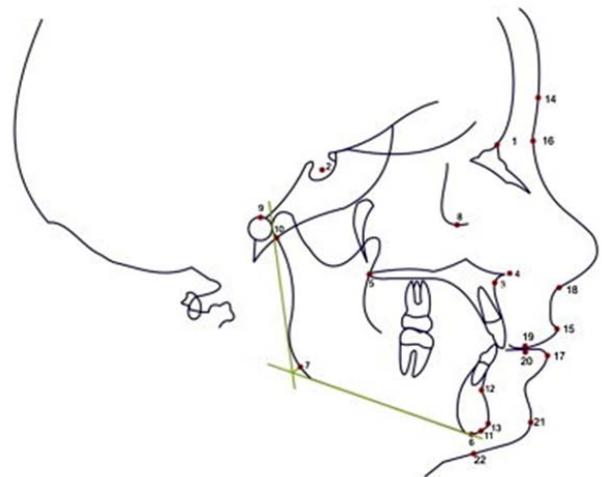


Figure 1. Cephalometric points and landmarks assessed in the study.

Hard tissue landmarks: 1. Nasion, 2. Sell, 3. Subspinale, 4. Anterior Nasal Spine, 5. Posterior Nasal Spine, 6. Menton, 7. Gonion, 8. Orbitale, 9. Porion, 10. Articulare, 11. Gnathion, 12. Supramentale, 13. Pogonion.

Soft tissue landmarks: 14. Glabella, 15. Labrale superius, 16. Soft tissue Nasion, 17. Labrale inferius, 18. Subnasale, 19. Stomion superius, 20. Stomion inferius, 21. Soft tissue Pogonion, 22. Soft tissue Menton.

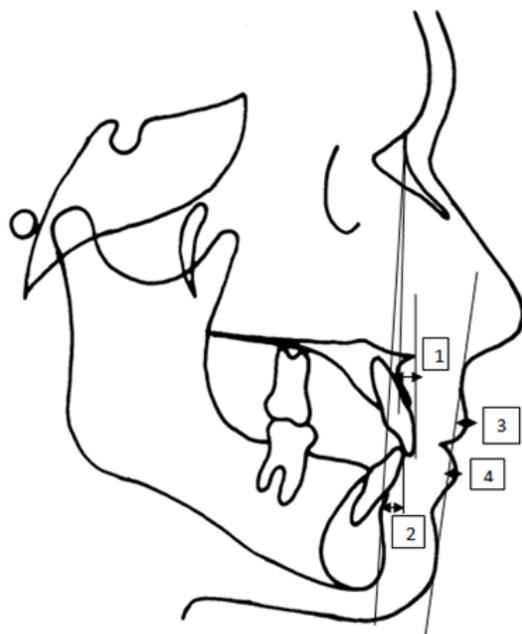


Figure 2. Linear measurements used in the cephalometric analysis. 1. UI to N-A, 2. LI to N-B, 3. UL-Sn-og, 4. LL-Sn-Pog.

Results were analyzed using SPSS statistical software version 16. Differences between variable measured by manual tracing and digitized images were calculated for the features of skeletal, dental and soft tissue measurements. The paired t - test was carried out to determine the significance of the variables at the 95% confidence level. In order to assess the agreement between the two methods, Concordance correlation coefficient and Kappa Statistics were calculated. Intra examiner error was evaluated by repeating tracings of randomly selected 10 radiographs (performed at the interval of 2 weeks) for manual and digital methods and the difference between the two sets of readings were analysed with the assessment of Cronbach's alpha value.

Results

The mean difference and standard deviation for each of the analysis and linear measurements on original radiographs are presented in Table 2. There was no significant difference in mean values of SNA, SNB, Occlusal – SN, GoGn to SN – plane angles, upper lip protrusion (UL-Sn-Pog) and lower lip protrusion (LL-Sn-Pog) in both manual and digital methods. However, mean values of distance between UI to N-A plane, UI-NA angle, LI-NB angle and inter incisal angles differed significantly in

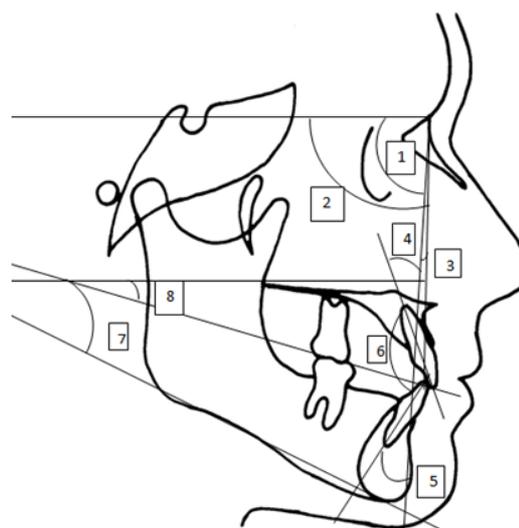


Figure 3. Angular measurements used in the cephalometric analysis. 1. SNA, 2. SNB, 3. ANB, 4. UI to N-A, 5. LI to N, 6. LI to UI, 7. GoGn to S-N, 8. Occl to S-N.

manual and digital methods (Table 1). All the measurement differences from each of these linear and angular cephalometric measurements were statistically significant except for the UI to NA linear measurement ($p < 0.05$). Concordance correlation coefficient and Kappa Statistics for measuring the agreement between two methods are shown in Table 2.

Both UI to NA and LI to NB linear measurements showed poor agreement (< 0.90) between the digital and manual methods in the assessment of Concordance correlation coefficient. Further, UI to NA, LI to NB angular measurements and inter incisal angle also showed poor agreement between two methods. These linear and angular measurements used to assess dento-alveolar relationship showed high total deviation index compare to the skeletal and soft analysis.

Most of the linear and angular measurements showed excellent and good intra examiner reliability except for the UI-NA linear measurement according to the Cronbach's alpha value (Table 3). UI-NA linear measurement showed slightly lower reliability compare to the other Cronbach's alpha values although which is acceptable. In the overall analysis of intra examiner variation for angular and linear measurements, Cronbach's alpha values were 0.917 and 0.945 respectively.

Table 1. Comparison for angular and linear measurements between manual and digital techniques

Variable	Paired Differences				t value	p-value	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
				Lower			Upper
SNA	-0.1960	0.3090	0.0437	-0.2838	-0.1082	-4.48	<0.001
SNB	-0.2420	0.3737	0.0528	-0.3482	-0.1358	-4.58	<0.001
ANB	0.0500	0.5661	0.0801	-0.1109	0.2109	0.62	0.535
Occl. to S-N	-0.2980	0.3706	0.0524	-0.4033	-0.1927	-5.69	<0.001
GoGn to S-N	-0.4720	0.5410	0.0765	-0.6257	-0.3183	-6.17	<0.001
U1 to N-A (mm)	3.90	7.30	1.03	1.83	5.98	3.78	<0.001
L1 to N-B (mm)	-21.798	6.137	0.868	-23.542	-20.054	-25.12	<0.001
L1 to U1 (Angle)	-2.65	7.89	1.12	-4.90	-0.41	-2.38	0.021
U1 to N-A (Angle)	2.624	5.297	0.749	1.118	4.130	3.50	0.001
L1 to N-B (Angle)	2.082	4.963	0.702	0.672	3.492	2.97	0.005
U lip protrusion (UL-Sn-Pog)	-0.0780	0.4432	0.0627	-0.2040	0.0480	-1.24	0.219
L lip protrusion (LL-Sn-Pog)	-0.3040	0.4040	0.0571	-0.4188	-0.1892	-5.32	<0.001

Table 2. Concordance correlation coefficient and Kappa statistics for measuring the agreement between the two methods

Variable	Concordance Correlation Coefficient (CCC)			Total Deviation Index (TDI)		
	Estimate	95% Confidence Intervals (CI)		Estimate	Standard Error	95% CI
		Lower CI	Upper CI			
SNA	0.9872	0.9781	0.9926	0.7094436	0.4684151	0.9878828
SNB	0.9768	0.9602	0.9865	0.8623612	0.6828322	1.0437005
ANB	0.9284	0.8776	0.9586	1.1139222	0.8243315	1.4022135
Occl. to S-N	0.8396	0.7443	0.9015	0.9096134	0.7339664	1.1094937
GoGn to S-N	0.9925	0.9872	0.9956	1.363644	1.189959	1.627361
U1 to N-A (mm)	0.1225	0	0.2693	16.130837	7.725161	25.421627
L1 to N-B (mm)	0.8258	0.7334	0.8882	2.889264	2.669739	3.475201
L1 to U1 (Angle)	0.7280	0.5706	0.8338	16.30588	12.40725	19.77147
U1 to N-A (Angle)	0.5690	0.3674	0.7195	11.536631	8.383029	14.678779
L1 to N-B (Angle)	0.7522	0.6083	0.8483	10.523859	8.344445	12.767222
U lip protrusion (UL-Sn-Pog)	0.9667	0.9425	0.9809	0.8819765	0.7320969	1.0163195
L lip protrusion (LL-Sn-Pog)	0.9633	0.9378	0.9784	0.9717334	0.8558138	1.1222019

Table 3. Cronbach's Alpha value for intra examiner variation

Variable	Cronbach's Alpha
SNA	0.997
SNB	0.999
ANB	0.990
Occl. to S-N	0.992
GoGn to S-N	1.000
U1 to N-A (mm)	0.775
L1 to N-B (mm)	0.985
L1 to U1	0.851
U1 to N-A	0.818
L1 to N-B	0.955
U lip protrusion - mm	0.998
L lip protrusion - mm	0.998
Overall angular and linear measures	
Linear measurements	0.945
Angular measurements	0.917

Discussion

Quantitative, systematic and objective measurements based on hard and soft tissue land marks of cephalometric radiographs are used in modern orthodontics. Precision and reproducibility of data obtained from the cephalogram is highly important in orthodontic treatment planning. However, errors in conventional methods have been reported with radiographic acquisition, land mark identification and measurements of cephalometric analysis [12].

With the advent of computer technology into orthodontics, there is ease of image archiving, image manipulation, transmission and enhancement reproducibility with digital cephalometry. However, with such development benefits, validity as well as the accuracy of digital cephalometry was raised among orthodontists [13].

The present study evaluated the reproducibility and reliability of commonly used angular and linear lateral cephalometric measurements with Steiner analysis obtained using a computerized program on digital radiographs and manual tracing methods. The software program for this study was Nemoceph version 06 and this program has not been adequately evaluated previously. Studies with regards to the conventional cephalometric analysis have identified most errors in magnification, tracing, landmark identification, obtaining measurements and recording [12].

Most researchers have identified the potential for distortion of the image at the time of transferring conventional cephalometric film to a digital format by

scanning [14]. However, the current study was conducted with digital lateral cephalogram for both digital and manual methods. Therefore, this study has minimized image transforming errors through scanning.

Further, cephalometry measurements could be altered due to errors in magnification and the present study relied on digital radiographs with similar magnification rather than scanned radiographs. However, manual tracing measurements were carried out on the hard copy printouts of digital radiographs. Some researchers have identified slight enlargement in hard copy printouts of digital radiographs, while highlighting that these differences were minimal and clinically acceptable [14,15].

Inter observer error also has been identified as a cause of low reliability and reproducibility of digital and conventional methods [16]. In the current study a single orthodontist with experience and competence in identification of cephalometric land marks performed both manual and digital tracings thus eliminating inter observer error. Intra examiner variability also can significantly contribute to errors of digital and manual methods. To eliminate the intra examiner errors, the tracing was performed twice in two weeks intervals for both manual and digital cephalometric tracing. Overall analysis of intra examiner variation for angular and linear measurements showed excellent correlation with Cronbach's alpha values. However, when assessed those values individually, UI-NA showed slightly lower reliability compared to rest of the cephalometric measurements. This slight intra examiner variation also can give rise to the deviation of UI-NA mean value in digital and manual methods.

Another most important source of error may arise due to the uncertainty in land mark identification. The current study has taken maximum measures to minimize the land mark identification error during the tracing stage with digital and conventional methods as the tracing was performed by a competent clinician. Further, to minimize the identification error only good quality radiographs were included in the study.

However, dento-alveolar measurements of UI-NA, and LI-NB parameters showed significant differences in the comparison of both methods. Due to such changes the inter incisal angle variation is inevitable. These dento-alveolar variations could be due to error in landmark identification of nasion and upper and lower incisor apices on the radiographs. Further, researchers have observed that when a landmark which is common to a pair of measurements is reused in analysis, the significant correlation between measurements may lead to error of measurements. Houston *et al* (1986) had identified and discussed that error of identifying a common landmark between linear or angular measurements may result in a purely topographic correlation between them and which may exaggerate a true biologic correlation [16,17].

Therefore, the most practical way to avoid this error is to measure the two variables independently on a separate tracing of each structure although this process would be more time consuming. Most of the previous studies have highlighted that it is impossible to estimate the position of landmarks without an error. However, it is important to make maximum efforts to minimize the error in landmark identification, especially the items with inherent lower reliability in digitized cephalometry. Further the impact of the error in landmark identification can be affected in two different ways. Those are the average value of measurements by all observers considered as gold standard for a specific landmark and distance between two landmarks. The distance between two landmarks will affect both the angular measurements and linear measurements. It has been found that especially in linear measurements, shorter the line segment measured the greater the percentage of error produced. Further, most of the studies have identified statistically significant reliability in measures taken to assess skeletal relationships and less reliability in dental measurements which is further confirmed by the current study [2,16].

The previous study conducted with NemocephNx version showed no significant difference in manual and digital measurements of the linear and angular cephalometric measures [18]. However, the current study showed slightly deviated results for the dento-alveolar assessment with the Nemoceph version 06. Similar results had been identified in relation to the LI-NB linear measurement with the study done with the Nemoceph version 06 [11]. However, that study had highlighted the more variations in linear measurements than the current study.

Conclusion

In conclusion, the validity of linear and angular measurements with the Nemoceph version 6 software and with the conventional method is highly correlated except for the UI to NA and LI-NB measurements. These dento-alveolar measurements with lower reliability should be reconsidered at the time of cephalometry analysis especially in relation to landmark identification in conventional method. Further research needs to be carried out on the evaluation of digital cephalometry with a larger sample size to ensure reproducibility and reliability of the cephalometric software program.

Conflicts of interest

There are no conflicts of interest.

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