Research Article

Reproducibility and speed of cephalometric tracing between manual versus digital method

Dr. Sanjay Prasad Gupta[1], Dr. Samarika Dahal[2], Dr. Shristi Rauniyar[3]

[1]Department of Orthodontics and Dentofacial Orthopedics, [2]Department of Oral Pathology and Forensic Dentistry, Tribhuvan University Teaching Hospital, MMC, Institute of Medicine, Tribhuvan University, Kathmandu, Nepal

[3]Dental Villa- Orthodontic Center & Speciality Dental Clinic, Kathmandu, Nepal

Corresponding author: Dr. Samarika Dahal; Email: drsamarika@gmail.com

ABSTRACT

Introduction: Cephalometric tracing is an indispensable method for the evaluation of the growth and development of the facial skeleton. The clinical implication of the tracing may be utilized in many branches of dentistry for diagnosis and treatment planning. The research based cephalometric tracing has been widely used over a period of time by various specialist. The purpose of this study was to compare the cephalometric tracing method between manual and the digital method.

Materials and Method: Lateral cephalometric radiographs of 120 patients who came for orthodontic treatment during Jan 2020 to Dec 2020 were randomly selected from Tribhuvan University Dental Teaching Hospital and one orthodontic center. Only the cephalograms with clarity and without artefacts were selected. The samples were randomly selected without any discremation of gender, occlusal type or skeletal pattern. The two methods were compared in terms of reproducibility and the speed of cephalometric tracing. The cephalograms were compared using both the manual and the digital method using Vistadent OC 1.1 software program (GAC International Inc, Bohemia, New York, USA). The mean tracing time for each method was also estimated. Paired t –test was used to compare the differences in individual measurement between the two methods. Intraclass correlation coefficients were used to measure the repeatability of the measurements.

Results: On comparing two methods, 3 out of 20 measurements showed statistically significant difference while others showed no statistically significant difference. The mean time needed to perform cephalometric analysis by the digital method (4.61±0.63 minutes) was significantly less as compared to the manual method (11.23±0.71 minutes) and the difference of performance duration were statistically significant (<0.05). Intraclass correlation coefficient showed strong correlation (0.86 to 0.99) for each repeated cephalometric measurements carried out by both manual and digital methods.

Conclusion: Both conventional manual and digital cephalometry methods showed good reproducibility with strong correlation for repeated measurements. The digital method exhibited significant reduction in time compared to manual method. Incorporation of digital methods by the clinicians can increase their efficiency.

KEYWORDS: Cephalometric tracing, Digital method, Manual method, Reproducibility, Speed of tracing

INTRODUCTION

Cephalometric radiography is one of the indispensable tools in orthodontics for studying growth and development of the facial skeleton, diagnosis and treatment planning, evaluating pre- and post-treatment changes and research work.[1,2,3] New emerging specialist forensic dentist can also do the collaborative projects with an orthodontist to establish base line data in Nepal.

Traditionally, cephalometric analysis was done on acetate overlays by tracing radiographic landmarks on it. Then the linear and the angular variables were measured. Despite its extensive use in orthodontics, the technique is associated with several limitations such as time consumption, high chance of error in landmark identification and measurement.[4,5] The radiographic film although quite stable, may deteriorate over time leading to loss of clarity in the radiographic image.

The accuracy of any method of analysis depends on the reproducibility of the measurements by the examiner. The recent advances have enabled us to perform cephalometric tracing digitally. The computer-based treatment planning significantly reduces the incidence of individual error. Also provides standardized, quick and accurate measurement with a high rate of reproducibility. Traditionally, computerized radiography was based on digitalization of the analogue data. With the recent advances direct digital images can be obtained and measured. The superior quality, instant image with reduced radiation and the facility to store and share makes it popular among the orthodontist. The elimination of the technique-sensitive developing processes, and the operator fatigue associated with the process are the additional advantages.[6,7,8]

There are innumerable computer-assisted cephalometric tracing programs available which needs to be analyzed. Several studies have attempted to compare the accuracy of the scanned, digitized, and digitally obtained radiographic measurement with that of traditional analogue radiographs.[9-14] Various studies have reported as not to have any measurement error in the digitilized cephalometric analysis as long as the landmarks were manually identified and marked.[15] Therefore, a better alternative is to manually identify a landmark on a digitally displayed screen images for cephalometric tracing. However, there are still some orthodontists who prefer manual method to digital, primarily due to the uncertainty of the financial investments in the software. Also, the trust they have for the conventional method over digital.[16]

The digital cephalometry to be accepted as an indispensable tool in orthodontics, the cephalometric analysis characterized by frequently used linear and angular measurements should be comparable to that on conventional radiographic film.[17]

Limited studies have evaluated the reproducibility and speed of orthodontic measurements using both manual and the digital methods. Moreover, no such study has been carried in our context. So, this study was aimed to compare, check for reproducibility and speed of cephalometric tracing between manual versus digital method. This study was conducted to fill this lacuna to widen the horizon for future researches based on these tracing which can be duly utilized by oral medicine, forensic dentistry and pediatric dentistry.

MATERIALS AND METHODS

The study comprised of 120 cephalometric radiographs of the patients who visited to the Department of Orthodontics and Dentofacial Orthopedics, Tribhuvan University Dental Teaching Hospital and Dental Villa- Orthodontic Center and Speciality dental clinic, Kathmandu for the purpose of orthodontic treatment during Jan 2020 to Dec 2020 were randomly selected. There was no discremination between gender, occlusal type, or skeletal pattern. Ethical approval was obtained from institutional review committee of Institute of Medicine before conducting this study (Ref. 399 (6-11) E^2 077/078).

Only the cephalograms with the clarity without any artefacts and those taken from the same source under same conditions with the standardized protocol were included in the study. Only the subjects standing with their head positioned in the cephalostat and teeth in the maximal intercuspation were included in this study. The radiographs with poor quality, with periapical pathology and radiographed from different source were excluded from the study.

To compare the two methods in terms of accuracy of individual measurements, the cephalograms were analysed by conventional manual method and digital method.

Manual method

The manual tracings were performed on clear acetate placed over the digital radiograph (printed on 1:1 ratio) using a 0.35 mm lead pencil. The tracings were done on a view box with the tracing paper securely positioned over the radiograph with a masking tape.

All hard and soft tissue landmarks were traced, with bilateral structures averaged to make a single landmark. All the tracings and measurements were performed by the same examiner (SPG).

After the tracing on the lateral cephalogram (Fig. 1), landmarks were identified and 20 cephalometric parameters such as SNA, SNB, ANB, Wits, Cond-A, Cond-Gn, Max-Mand, NSAr, SArGo, ArGoMe, SN-GoGn, FMA, ANS-Me, Max1-NA, Max1-SN, Mand1-NB, IMPA, Mx1-Mn1, UL-E and LL-E were analyzed. Among 20 cephalometric parameters- 13 were skeletal parameters, 5 were dental parameters and 2 were soft tissue parameters (Table 1).

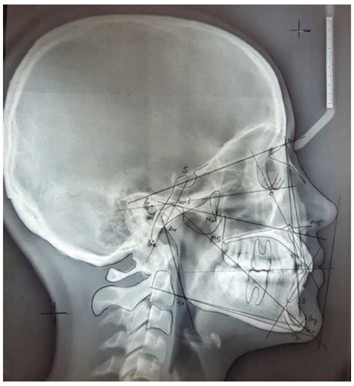

Fig. 1 Cephalometric parameters on lateral cephalogram by manual method

Table 1: The cephalometric variables evaluated in this study

Skeletal Parameters
SNA=Angle determined by points S, N and A
SNB=Angle determined by points S, N and B
ANB=Angle determined by points A, N and B
Wits=Linear diastance from AO to BO
Cond-A=Distance from condylion to point A (Maxillary length)
Cond-GnDistance from condylion to gnathion (Mandibular length)
Max-Mand=Difference between of maxillary and mandibular length
NSAr=Angle determined by points N, S and Ar
SArGo=Angle determined by points S, Ar and Go
ArGoMe=Angle determined by points Ar, Go and Me
SN-GoGn=Angle formed between SN plane and the mandibular plane
FMA=Angle formed between FH plane and the mandibular plane
ANS-Me=Distance between anterior nasal spine to menton
Dental Parameters
Max1-NA=Angle formed by the intersection of the maxillary incisor axis to the plane between points N and A
Max1-SN=Angle formed by the intersection of the maxillary incisor axis to the SN plane
Mand1-NB=Angle formed by the intersection of the mandibular incisor axis to the plane between points N and B.
IMPA=Angle formed by the intersection of the mandibular incisor axis to the mandibular plane
Mx1-Mn1=Angle formed by the intersection of the mandibular incisor axis to the maxillary incisor axis
Soft tissue parameters
UL-E=Perpendicular distance from the upper lip point to E line
LL-E=Perpendicular distance from the lower lip point to E line

Digital method

The digitalized measurements were done in direct digital images imported to the Vistadent OC 1.1 software program (GAC International Inc, Bohemia, New York, USA), which automatically generated measurements from the selected landmarks. The landmarks were manually identified and marked with the help of mouse cursor. Twenty cephalometric measurements were carried out (Fig. 2).

Prior to the digitization of landmarks, all images were calibrated by digitizing two points on the ruler contained within the program's digital cassette. The observer was able to adjust the image using enhancement functions for magnification, brightness, and contrast.

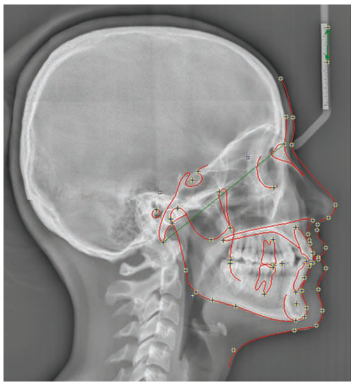

Fig. 2 Cephalometric parameters on lateral cephalogram by digital method

Speed of tracing

The procedures of tracing, landmark identification, and measurement were followed step by step, and the time spent for each procedure was recorded in minutes. The mean tracing time for each method was calculated.

Intra-examiner reliability

To determine intra-examiner repeatability, 40 radiographs from the original 120 radiographs were randomly selected and retraced and remeasured by the same authors (SPG), using both the manual and digital tracing techniques, 2 weeks after the first tracings.

Data obtained were transferred to MS-excel sheet.

The data were verified and analysed statistically using SPSS Statistics Version 21.0 (Armonk, NY: IBM Corp.) with confidence level set at 95% (P < 0.05) to test for significance. Measurement of repeatability were evaluated by calculating intraclass correlation coefficients (r2), and paired t-test was used to compare differences in individual measurements between two methods.

RESULTS

The mean values with standard deviations and the differences for each of the 20 measurements obtained with the manual and digital methods are shown in Table 2. On comparing two methods, only 3 out of 20 measurements like Cond-A, FMA and UL-E showed statistically significant difference while others showed no statistically significant difference.

Table 2: Comparison of cephalometric measurements obtained from manual and digital method

Cephalometric Parameters	Manual measurement (Mean±SD)	Digital measurement (Mean±SD)	Difference between measurements	p-value (paired t-test)
SNA (°)	80.88±3.62	80.88±3.14	-0.11±2.21	0.50
SNB (°)	76.22±3.49	74.78±2.66	-1.43±2.11	0.10
ANB (°)	4.66±3.12	6.06±3.05	1.4±1.59	0.14
Wits (mm)	2.05±2.72	2.55±2.00	0.5±2.48	0.34
Cond-A (mm)	88.77±7.67	94.11±7.83	5.33±2.87	0.01*
Cond-Gn (mm)	114.77±8.92	116.88±10.46	2.11±2.13	0.14
Max-Mand (mm)	25.66±5,47	25.44±6.24	-0.22±2.01	0.46
NSAr (°)	129.66±6.94	130.33±6.53	0.66±3.57	0.38
SArGo (°)	140.66±5.39	140.22±4.99	-0.44±2.1	0.40
ArGoMe (°)	125.55±4.55	124.55±5.61	-1±2.67	0.31
SN-GoGn (°)	32.33±4.89	30.08±5.35	-2.24±1.27	0.16
FMA (°)	25.66±3.16	22.88±5.10	-2.77±2.89	0.03*
ANS-Me (mm)	67.66±6.04	67.55±6.40	-0.11±1.26	0.40
Max1-NA (°)	24.77±9.88	21.48±11.48	-3.28±2.16	0.13
Max1-SN (°)	104.55±8.95	102.44±9.16	-2.11±1.41	0.14
Mand1-NB (°)	30.88±6	27.466±6.14	-3.42±2.54	0.11
IMPA (°)	98.66±4.41	98.11±6.71	-0.55±2.43	0.41
Mx1-Mn1 (°)	120.55±7.43	119.81±9.21	-0.744±1.89	0.36
UL-E (mm)	-2.11±2.89	-1.77±2.90	0.33±0.43	0.02*
LL-E (mm)	0.44±2.49	0.61±2.26	0.16±0.43	0.14

(*p<0.05= Statistically significant)

Mean time needed to perform cephalometric analysis by both the manual and digital methods are depicted in Table 3. The difference between mean tracing time between manual and digital methods showed statistically significant difference (p=0.01).

Table 3: Mean time needed to perform cephalometric Analysis by manual and digital method

Tracing method	Mean tracing time (Minutes)	p-value
Manual method	11.23±0.71	
Digital method	4.61±0.63	
Difference	6.62±0.84	0.01*

Intraclass correlation coefficient (r^2) to determine the intra-examiner repeatability were calculated for both the methods are shown in Table 4. The ICC value of each parameter for repeated measurement were ranged from 0.86 to 0.99 for manual method whereas 0.87 to 0.99 for digital method that showed strong correlation as ICC is greater than 0.85.

Table 4: Intraclass correlation coefficient of manual and digital method for intraexamier repeatability

Cephalometric Parameters	Manual tracing- 1st and second measurement (ICC at 95%)	Digital tracing- 1st and second measurement (ICC at 95%)
SNA (°)	0.96	0.97
SNB (°)	0.94	0.91
ANB (°)	0.93	0.92
Wits (mm)	0.94	0.91
Cond-A (mm)	0.96	0.99
Cond-Gn (mm)	0.99	0.96
Max-Mand (mm)	0.96	0.95
NSAr (°)	0.89	0.91
SArGo (°)	0.93	0.99
ArGoMe (°)	0.92	0.88
SN-GoGn (°)	0.96	0.99
FMA (°)	0.95	0.93
ANS-Me (mm)	0.97	0.94
Max1-NA (°)	0.97	0.98
Max1-SN (°)	0.91	0.93
Mand1-NB (°)	0.97	0.95
IMPA (°)	0.86	0.96
Mx1-Mn1 (°)	0.98	0.91
UL-E (mm)	0.96	0.87
LL-E (mm)	0.98	0.92

DISCUSSION

Previously, manual-tracing method was considered to be the best for the cephalometric analysis. Along with the other limitation with the technique, error in landmark identification is one of the major concerns.[2,18,19,20] It can depend on various parameters such as visual performance, training, and experience of the clinician along with the density and sharpness of the image.[21] The image acquisition and measurement errors are responsible for the reproducibility errors. Acquisition errors are dependent on the errors during exposure or computer processing of cephalometric radiographs. The measuring devices or the technique errors are responsible for the measurement errors.[22]

The introduction of digitalization in orthodontics has dramatically increased the efficiency of the specialist as its less time consuming and user friendly. Although, the landmarks are located manually, the computer system completes the analysis. This digitilized method can eliminate the errors during the lines drawing with a ruler and measuring the angles with a protractor.[23]

On the contrary, if the landmarks are determined by hand during computerized cephalometric analysis, then the measurement errors are the same as the manual technique.[24] In this study, the landmark identification was carried out manually on digital images using a mouse-driven cursor. The measurements were determined automatically by the software.

The cephalometric variables used in this study were commonly used variables for the purpose of orthodontic diagnosis, treatment planning, and for the evaluation of treatment results.

In our study, out of 20 cephalometric parameters, only three parameters like Cond-A, FMA and UL-E showed statistically significant difference while others showed no statistically significant difference during comparison of the mean cephalometric values obtained by both the methods. These findings were consistent with the findings of the study conducted by Chen et al[25] and Paixao et al[26] who reported no significant differences between both the methods. Shah et al[17] and Agrawal et al[27] concluded that digital measurements were comparable to manual method although some parameters showed statistically significant difference. On the contrary, Kamath et al[28] reported statistically significant difference exists between both the methods.

In this study, the mean time needed to perform cephalometric analysis by the digital method is significantly less as compared to the manual method. These findings are similar to the study of İşeri et al.[29] and Uysal et al[30] that showed examiners spent less time during computer-assisted tracing as compared to conventional manual tracing. Our findings are also consistent with the study by Chen et al which showed significantly less time required to perform cephalometric analysis by using digital method than that with traditional manual tracing method.[25]

Intraclass correlation coefficient (r^2) were calculated to determine the intra-examiner repeatability for reliability of cephalometric measurement which showed strong correlation for both manual and digital methods as ICC values were ranged from 0.86 to 0.99. These findings are consistent with the study of Uysal et al and Agrawal et al.[27,30] Hence, digital cephalometric analysis method can be reliably used with good accuracy in routine clinical practice as it significantly reduces the performing duration as compared to the conventional manual tracing method.

However, to validate these results further research comparing various available cephalometric softwares for their accuracy and reliability is required.

CONCLUSION

Both manual and digital methods showed good reproducibility for most of the cephalometric parameters. Along with this, both methods showed strong correlation for repeated measurements. Compared to manual method, digital method provides a significant time reduction for cephalometric analysis which can provide benefits to the clinician in carrying out cephalometric analysis.

OJN

REFERENCES

1. Ricketts RM. Perspectives in clinical application of cephalometrics. Angle Orthod. 1981; 51:115–150.
2. Baumrind S and Frantz RC. The reliability of head film measurements 1. Landmark identification. Am J Orthod 1971a; 60:111–127.
3. Brodie AG. On the growth pattern of the human head from the third month to the eighth year of life. Am J Anat. 1941; 68:209–262.
4. Sandler PJ. Reproducibility of cephalometric measurements. Br J Orthod. 1988; 15:105 – 110.
5. Baumrind S, Frantz RC. The reliability of head film measurements 2. Conventional angular and linear measures. Am J Orthod. 1971b; 60:505–517.
6. Brennan J. An introduction to digital radiography in dentistry. J Orthod. 2002; 29:66–69.
7. Quintero JC, Trosien A, Hatcher D, Kapila S. Craniofacial imaging in orthodontics: historical perspective, current status, and future developments. Angle Orthod. 1999; 69:491–506.
8. Sayinsu K, Isik F, Trakyali G, Arun T. An evaluation of the errors in cephalometric measurements on scanned cephalometric images and conventional tracing. Eur J Orthod 2007; 29:105–108.
9. Nimkarn Y, Miles PG. Reliability of computer-generated cephalometrics. Int J Adult Orthodon Orthognath Surg. 1995; 10:43–52.
10. Geelen W, Wenzel A, Gotfredsen E, Kruger M, Hansson LG. Reproducibility of cephalometric landmarks in conventional film, hardcopy and monitor-displayed images obtained by the storage phosphor technique . Eur J Orthod 1998; 20:331–340.
11. Chen YJ, Chen SK, Chan HF, Chen KC. Comparison of landmark identifi cation in traditional versus computer-aided digital cephalometry. Angle Orthod. 2000; 70:387–392.

12. Gregston MD, Kula T, Hardman P, Glaros A, Kula K. Comparison of conventional and digital radiographic methods and cephalometric analysis software: I. Hard tissue. Semin Orthod. 2004; 10:204–211.
13. Macrì V. and Wenzel A. Reliability of landmark recording on fi lm and digital lateral cephalograms. Eur J Orthod. 1993; 15:137–148.
14. Ongkosuwito EM, Katsaros C, Van't Hof MA, Bodegom JC, Kuijpers- Jagtman AM. The reproducibility of cephalometric measurements: a comparison of analogue and digital methods. Eur J Orthod 2002; 24:655–665.
15. Enlow DH, Hans MG. Essentials of Facial Growth. Philadelphia: W.B. Saunders; 1996.
16. Tanwani HB, Potnis SS, Baralay SS, Patil SS. Comparison of conventional and digital cephalometric analysis: A pilot study. J Dent Allied Sci 2014; 3:80 4.
17. Shah AR, Karandikar G, Ravindranath VK, Sonawane M, Mhatre A. A comparative study of reliability and accuracy of manual and digital lateral cephalogram tracing. J Contemp Dent. 2016; 6:15-18.
18. Mitgård J, Björk G, Linder-Aronson S. Reproducibility of cephalometric landmarks and errors of measurements of cephalometric cranial distances. Angle Orthod. 1974; 44: 56–61.
19. Houston WJB. The analysis of errors in orthodontic measurements. Am J Orthod. 1983; 83:382–390
20. Houston WJB, Maher R E, McElroy D, Sherriff M. Sources of error in measurements from cephalometric radiographs. Eur J Orthod. 1986; 8:149–151
21. Björk A, Solow B. Measurements on radiographs. J Dent Res. 1961; 41:672–683.
22. Onkosuwito E M, Katsaros C, van't Hof M A, Bodegom J C, Kuipers- Jagtman A M. The reproducibility of cephalometric measurements: a comparison of analogue and digital methods. Eur J Orthod. 2002; 24:655–665.
23. Liu JK, Chen YT, Cheng KS. Accuracy of computerized automatic identification of cephalometric landmarks. Am J Orthod. 2000; 118:535–540
24. Gravely JF, Benzies PM. The clinical significance of tracing error in cephalometry. Br J Orthod, 1974;1: 95–101.
25. Chen SK, Chen YJ, Yao CC et al. Enhanced speed and precision of measurement in a computer-assisted digital cephalometricanalysis system. Angle Orthod. 2004;74:501–507.
26. Paixao MB, Sobral MC, Vogel CJ, et al. Comparative study between manual and digital cephalometric tracing using Dolphin Imaging software with lateral radiographs. Dental Press J Orthod. 2010;15:123–130.
27. Agrawal MS, Agrawal JM, Patni V, Nanjannawar L. An evaluation of the reproducibility of landmark identification in traditional versus computer-assisted digital cephalometric analysis system. APOS Trends Orthod 2015;5:103-10.
28. Kamath MK, Arun AV. Comparison of cephalometric readings between manual tracing and digital software tracing: A pilot study. Int J Orthod Rehabil 2016;7:135-8.
29. İşeri H, Açıkbaş A, Yılmaz O. Bilgisayar metodu ve geleneksel metod ile yapılan sefalometrik ölçümlerin hassasiyet, tekrarlanabilirlik ve zaman açısından değerlendirilmesi. Turk J Orthod. 1992; 5:1–6 (English abstract)
30. Uysal T, Baysal A, Yagci A. Evaluation of speed, repeatability, and reproducibility of digital radiography with manual versus computer-assisted cephalometric analyses. Eur J Orthod. 2009; 31:523–528.