ACCURACY OF LINEAR CEPHALOMETRIC MEASUREMENTS WITH SCANNED LATERAL CEPHALOGRAMS

[1]SOHRAB SHAHEED, BDS, FCPS
[2]AYESHA IFTIKHAR, BDS
[3]GHULAM RASOOL, BDS, MCPS, FCPS
[4]ULFAT BASHIR, BDS, MCPS, FCPS

ABSTRACT

Digital Cephalometry needs to be as accurate as conventional cephalometry in order to be taken as a standard of care in contemporary orthodontics. Objective of this study was to compare the accuracy of linear cephalometric measurements on scanned cephalograms with manual tracing as the gold standard. Cephalometric analysis of specified linear measurements was performed on cephalometric radiographs manually. Radiographs were subsequently scanned and the images were analyzed digitally with a computer software for the same measurements. Paired sample t tests were used for statistical significance ($p<0.05$). Clinical significance was set as more than 2mm difference between the methods for any linear measurement. Cephalometric comparisons between original and digital images showed statistically significant differences for S-Go, N-Me and ANS-Me. None of the means of the difference between the two methods exceeded 2mm. Although some measurements showed statistically significant differences, the difference was regarded as clinically insignificant. Scanned cephalograms can be safely used for linear cephalometric analysis.

Key words: *Cephalometry; Cephalometric Analysis; Digital Cephalometry*

INTRODUCTION

Digital cephalometry offers advantages of automated analysis, photograph and radiograph archiving, cephalometric image enhancement, information sharing and even the ability to construct 3D images. Such benefits have popularized these softwares among orthodontists. The evolution of advancements in digital cephalometry has been critically evaluated for accuracy, applicability and reliability of these methods.[1-4]

Traditionally, the analyses of lateral cephalograms have been carried out on paper, using different anatomical and constructed landmarks and studying their relationship to each other by different angular and linear measurements. Therefore, for digital cephalometry to be a better tool in clinical orthodontics, the cephalometric analysis, represented by widely used linear and angular measurements, must be as comparable and reliable as it is on conventional radiographic film, which is still considered as the golden standard in contemporary orthodontics.[2,5]

Recently, the improvement in scanning equipment and its low cost consumer grade availability has provided an easy way of archiving the cephalograms.[1,4] A previous study evaluated the accuracy of angular measurements with scanned lateral cephalograms.[6] This study aims to compare linear cephalometric analysis performed via the classic method of manual tracing with a computerized method using cephalometric software (Viewbox 4.0™), where the lateral cephalograms will be scanned and then digitized onscreen.

[1] **Correspondence:** Assistant Professor, Department of Orthodontics, Islamic International Dental Hospital, Riphah International University, Islamabad. s.shaheed@ymail.com Contact No: 03339327608
[2] Post Graduate Resident Year III, Department of Orthodontics, Islamic International Dental Hospital
[3] Associate Professor, Department of Orthodontics, Khyber College of Dentistry, Peshawar
[4] Professor and Head, Department of Orthodontics, Islamic International Dental Hospital, Riphah International University, Islamabad

METHODOLOGY

One hundred consecutive cephalograms with reasonable clarity and good contrast were selected from the records of the Islamic International Dental Hospital patients who commenced their orthodontic treatment in the year 2008. This cross-sectional validation study was conducted over a period of six months starting July-Dec 2008. As per departmental protocol, informed consent was taken at the time of procuring pre-treatment records. All the lateral cephalograms were taken by the same operator on Rotograph Plus at 80 kvp, 10 mA and 0.8-second exposure time using 8 ×10 inch Kodak green film with the patient's head in natural posture position. Cephalograms with unerupted or missing incisors, unerupted or partially erupted teeth overlying the apices of the incisors and evidence of craniofacial syndromes or anomalies were excluded from the study.

Four fiducial points, labeled A, B, C and D, at predetermined distances were indexed in four radiographs which were randomly selected. This was done in order to rule out any distortion associated with scanning of the radiograph.

All the radiographs were first traced manually with an acetate paper attached to their surfaces. Tracing was carried out with a lead pencil in a dark room on a radiograph viewer. Landmark identification was performed on each radiograph. The landmarks identified are listed in Table 1. A set of linear measurements commonly used in the orthodontic department of IIDH were obtained with the help of a standard ruler. (Table 2) Twenty tracings were repeated again with a minimum of one month in between each tracing to check for intra-observer reliability of the measurements.

Each radiograph and manual tracing was then scanned with HP Scanjet 2400 Scanner in JPEG format with 24 bit color, 150 dpi (dots per inch) and 1200 x 1600 pixels.[7-12] The images were imported into the Viewbox™ 4.0 Software (dHAL Orthodontic Software, Athens, Greece). The radiographs were then digitized. The same landmarks were identified and digitized on-screen to get a digital tracing. The digitization of twenty radiographs was also repeated after a month for intra-observer error. All the manual and digital calculations were then compared with the manual method, which was our gold standard. The null hypothesis was that there is no difference in the accuracy of linear measurements between the manually traced and scanned lateral cephalograms. Accuracy was defined as concordance of the digitally obtained linear measurements with the manually calculated linear measurements.

All statistical calculations were carried out with the SPSS software Version 11 (Chicago, Ill). Paired *t* test were used to evaluate statistical significance for comparing mean values between corresponding data sets. Statistical significance was set at $P < 0.05$. Intra class correlation coefficients were used to rule out intra observer error. An r value of <0.75 was considered as a weak correlation. Clinical significance was set at e”2mm difference for any measurement between the manual and digital method as proposed by McClure et al.[13]

TABLE 1: LANDMARKS IDENTIFIED IN THIS STUDY

N:	Nasion	Pog':	Soft tissue pogonion
S:	Sella	ANS:	Anterior nasal spine
Me:	Menton	Ls:	Upper lip point
Go:	Gonion	Li:	Lower Lip Point
Pn:	Pronasale		

TABLE 2: THE CEPHALOMETRIC VARIABLES USED IN THE STUDY AND DEFINITIONS

SN	(mm)	Distance between points S and N
S – Go	(mm)	Distance between points S and Go
N – Me	(mm)	Distance between points N and Me
Ans – Me	(mm)	Distance between points Ans and Me
Jarabak	(%)	The ratio between posterior and anterior face heights (S – Go/N – Me) x 100
AnsMe/ NMe	(%)	Ratio of lower (Ans – Me) to total (N – Me) face Height x 100
ULE	(mm)	Perpendicular distance from the upper lip point to E line
LLE	(mm)	Perpendicular distance from the lower lip point to E line

TABLE 3: AGE AND GENDER DESCRIPTIVE STATISTICS

GENDER	Number	Age	
		Mean	S.D
Male	34	16.68	3.70
Female	66	16.20	3.35
Total	100	16.37	3.47

RESULTS

A total of hundred pretreatment cephalometric radiographs of patients were analyzed. The descriptive statistics of subjects according to age and gender is given in Table 3.

Table also shows that the mean age of the entire sample was 16 years 4 months (minimum 10 years and maximum 25 years). Mean age of the male group was 16 years 8 months (minimum 10 years and maximum 25 years). Mean age of the female group was 16 years 2 months (minimum 10 years and maximum 24 years).

Fiducial measurements were subjected to paired student t test with p value set at 0.05. Statistically significant differences were found for all fiducial measurements.

Means, standard deviations and *p* values for the 8 linear measurements are presented in the table 4. The data was subjected to paired student t test with p value set at 0.05. Statistically significant differences were found for linear variables ANS-Me, N-Me and S-Go. The difference was highly significant for S-Go (p=0.000) which also showed highest mean difference (-1.655).

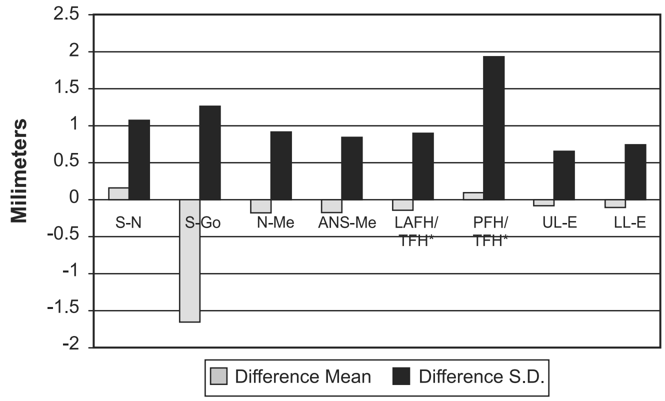

Fig 1: Linear Measurements: Mean Differences and Standard Deviations

TABLE 4: COMPARISON OF LINEAR MEASUREMENTS

	Manual		Digital		Sig.
	Mean	**S.D.**	**Mean**	**S.D.**	
S-N	71.167	4.158	71.007	4.208	.105
S-Go	76.804	6.649	78.459	6.565	.000
N-Me	121.863	8.663	122.039	8.639	.037
ANS-Me	69.526	7.861	69.700	7.811	.026
LAFH/TFH*	56.873	3.910	57.019	3.757	.077
PFH/AFH**	64.502	5.496	64.403	5.363	.576
UL-E	-3.242	3.285	-3.163	3.157	.189
LL-E	-.631	4.128	-.528	3.834	.134

* % of Lower Anterior Facial Height to Total Facial Height ratio (ANS-Me / N-Me)
** % of Posterior Facial Height to Anterior Facial Height ratio (S-Go / N-Me)

TABLE 5: CORRELATION OF INTRA-OPERATOR LINEAR MEASURMENTS AND RATIOS

Linear measurements	Mean Difference		Correlation	
	M	**D**	**M**	**D**
S-N	-.050	-.285	.985	.976
S-Go	-.375	-.310	.991	.973
N-Me	.075	-.030	.990	.998
ANS-Me	.325	.145	.993	.992
LAFH/TFH*	.225	.142	.977	.978
PFH/AFH**	1.663	-.208	.946	.955
UL-E	.100	-.285	.898	.979
LL-E	-.125	-.100	.967	.992

* % of Lower Anterior Facial Height to Total Facial Height ratio (ANS-Me / N-Me)
** % of Posterior Facial Height to Anterior Facial Height ratio (S-Go / N-Me)

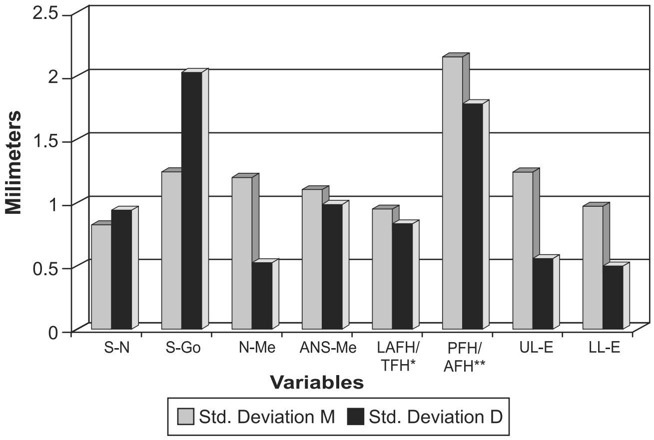

Fig 2: Intra Operator Reliability: Standard Deviations

The ratio ANS-Me/N-Me showed *p* value close to our threshold (p=0.077). The ratio S-Go/N-Me showed S.D. of 1.9% but was statistically insignificant (Fig 1). Highly significant correlations were found for all measurements indicating good reliability (Table 5). S-Go and S-Go/N-Me ratio had higher standard deviations than the rest of the measurements. (Fig 2)

DISCUSSION

The purpose of this investigation was to assess the accuracy of the linear cephalometric measurements on scanned lateral cephalograms with the help of a computer software. As the conversion of an analogue image to digital format involves many steps such as the hardware, software, computer functions and settings, the likelihood of image distortion is increased. Further distortion can be expected if the storage format of the digital image is to be changed e.g. from TIFF to JPEG format, as it can involve compression and alteration of the image. Similarly if an attempt is made to have a hard copy print of the digital image, involvement of a peripheral printing device is another potential distortion source. All of these factors need to be considered when assessing the distortion of a digital image.[1,4,7-12]

The results of the fiducial measurements indicated a distortion of 0.4% in both horizontal and vertical dimensions for the scanning process. Macri[14] and Wenzel[15] reported 2% vertical enlargement for video-captured cephalograms. Bruntz[1] reported 0.5% enlargement in vertical dimension and 0.3% reduction in horizontal dimensions with scanned cephalograms. The difference can be attributed to the different image capturing equipment as well as the varied specifications of the scanners.

In present study, 3 out of 8 measurements that showed significant differences were S-Go, N-Me and ANS-Me. Difference in S-Go can be explained with the uncertainty in locating Gonion on digital images as mentioned in the previous investigation about the angular measurements. On the other hand, the error at landmark Me is in general reported to be within the acceptable range to be considered precise, probably due to the direction-oriented definition of Me (most inferior) on the well-defined outline of mandibular symphysis. At Go, however, there is both a greater magnitude as well as distribution of error that renders some measurements e.g. S-Go as less reliable as compared to others such as S-N. This study supports the fact that magnitude of error at Go is more than at any other landmark studied with high S.D. values for inter and intra rater reliability measurements involving Go landmark. An additional factor can be the overall magnification during the scanning process, which possibly accounted for the differences in the measurements of N-Me and ANS-Me as well, which showed consistently higher values for digital measurements.[16]

The ratios measured as a percentage in this study did not show statistically significant results; however the ratio of posterior facial height to anterior facial height which involved the landmark Gonion (S-Go/N-Me), showed highest standard deviations for any measurement recorded, attributable to point Gonion's inherent poor reliability.[16]

Reliability is an important aspect of measurement. If a measure cannot be reproduced consistently, then the value (cost, time, and patient treatment decisions) of the methodology is questionable. The most important factor influencing the reliability of landmark identification in the present study, as outlined by several previous studies, was observed to be the nature of cephalometric landmark itself. We found that both the inter- and intra-observer error on digital image was generally smaller than that on the film except point Go in vertical axis as evidenced by high standard deviations. The smaller S.D. indicated the better reliability. In a clinical situation such as orthodontics, a reproducibility that is within 2° or 2 mm will probably not make a difference in treatment. Standard deviation can be used as a parameter to indicate variability in measurement of central tendency. Similarly, if a new method of cephalometric analysis is not as accurate as an already established method; the validity of the new method becomes questionable.[13]

None of the digital and manual measurements exceeded these criteria. Also, most of the significant differences between digital and manual comparisons included landmarks using root apices, Point A and Go. The null hypothesis was rejected in statistical terms, but in general it can be concluded that the scanned images of lateral cephalograms are equally acceptable and reliable *clinically* as conventional cephalometric films.

CONCLUSION

None of the differences in landmark identification error between the film-based and digital methods, including the statistically significant differences, was greater than 2 units of measurements (degrees). This indicates that even the statistically significant differences between the two methods of cephalometric analyses were unlikely to be of any clinical significance. Scanned images of lateral cephalogram are equally accurate and reliable clinically for linear cephalometric analysis.

Acknowledgement

We are immensely thankful to Mr Demetrios Halozenetis, Assistant professor, Orthodontic Department, University of Athens Dental School, Athens, Greece, for providing us the Viewbox Software free of charge for research purposes.

REFERENCES

1 Bruntz LQ, Palomo JM, Baden S, Hans MG. A comparison of scanned lateral cephalograms with corresponding original radiographs. Am J Orthod Dentofacial Orthop 2006;130(3): 340-48.

2 Kazandjian S, Kiliaridis S, Mavropoulos A. Validity and reliability of a new edge-based computerized method for identification of cephalometric landmarks. Angle Orthod 2006; 76(4):619-24.

3 Santoro M, Jarjoura K, Cangialosi TJ. Accuracy of digital and analogue cephalometric measurements assessed with the sandwich technique. Am J Orthod Dentofacial Orthop 2006;129(3):345-51.

4 Sayinsu K, Isik F, Trakyali G, Arun T. An evaluation of the errors in cephalometric measurements on scanned cephalometric images and conventional tracings. Eur J Orthod 2007; 29(1):105-08.

5 Chen YJ, Chen SK, Huang HW, Yao CC, Chang HF. Reliability of landmark identification in cephalometric radiography acquired by a storage phosphor imaging system. Dentomaxillofac Radiol 2004;33(5):301-06.

6 Shaheed S, Bashir U, Arshad N. Accuracy of angular cephalometric measurements with scanned lateral cephalograms. Pak Oral Dental J 2009;29:269-74.

7 Chen YJ, Chen SK, Yao JC, Chang HF. The effects of differences in landmark identification on the cephalometric measurements in traditional versus digitized cephalometry. Angle Orthod 2004;74(2):155-61.

8 Turner PJ, Weerakone S. An evaluation of the reproducibility of landmark identification using scanned cephalometric images. J Orthod 2001;28(3):221-29.

9 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(6):655-65.

10 Halazonetis DJ. At what resolution should I scan cephalometric radiographs? Am J Orthod Dentofacial Orthop 2004;125(1):118-19.

11 Schulze RK, Gloede MB, Doll GM. Landmark identification on direct digital versus film-based cephalometric radiographs: a human skull study. Am J Orthod Dentofacial Orthop 2002;122(6):635-42.

12 Naoumova J, Lindman R. A comparison of manual traced images and corresponding scanned radiographs digitally traced. Eur J Orthod 2009;31(3):247-53.

13 McClure SR, Sadowsky PL, Ferreira A, Jacobson A. Reliability of Digital versus Conventional Cephalometric Radiology: A Comparative Evaluation of Landmark Identification Error. Semin Orthod 2005;11:98-110.

14 Macri V, Athanasiou AE. Sources of error in lateral cephalometry. In: Athanasiou AE, editor. Orthodontic Cephalometry. London: Mosby-Wolfe; 1997. p. 125-60.

15 Wenzel A, Gotfredsen E. Digital radiography for the orthodontist. Am J Orthod Dentofacial Orthop. 2002;121(2):231-35.

16 Roden-Johnson D, English J, Gallerano R. Comparison of hand-traced and computerized cephalograms: landmark identification, measurement, and superimposition accuracy. Am J Orthod Dentofacial Orthop 2008;133(4):556-64.