ACCURACY OF ANGULAR CEPHALOMETRIC MEASUREMENTS WITH SCANNED LATERAL CEPHALOGRAMS

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ABSTRACT

Digital Cephalometry is fast becoming the standard of care in contemporary orthodontic diagnosis. Before it can completely take over the traditional methods, it must be demonstrated that it is as accurate as conventional cephalometric radiography.

This study was done to compare the accuracy of angular cephalometric measurements on scanned cephalograms with manual tracing as the gold standard.

Cephalometric analysis of specified angular 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 2° difference between the methods for any angular measurement.

Cephalometric comparisons between original and digital images showed statistically significant differences for SNA, MMA, IMPA and Nasolabial angles. None of the means of the difference between the two methods exceeded 1°.

Although some measurements showed statistically significant differences, the difference was regarded as clinically insignificant. Scanned cephalograms can be safely used for angular cephalometric analysis.

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

INTRODUCTION

Cephalometric radiography is a valuable aid in diagnosis, treatment planning and predicting treatment outcome in current orthodontic practice.[1-4] The proper analyses of these cephalograms rely on accurate identification and location of carefully defined anatomical and constructed landmarks on human facial skeleton.[5-7] Therefore, the quest to minimize errors arising from the acquisition of radiographs, tracing, landmark identification, and measurements has led to extensive study in this field.[1,2,4,8]

The advent of the computer age in past two decades marked the emergence of new methods for obtaining and analyzing radiographic images.[1] Such efforts included the transfer of the overlay paper tracing to digitizers, direct digitization with photo-stimulatable phosphor plates and capturing of the radiographic image followed by on-screen digitization using a computer software. The evolution of such advancements has been critically evaluated throughout the course, and has resulted in improved accuracy, applicability and reliability of these methods.[5,7] The additional benefits of automated analysis, photograph and radiograph archiving, image enhancement features, information sharing and now the ability to construct 3D images have made such softwares being fast adopted by orthodontists around the globe.

Chen et al[5,6] concluded that 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 compa-

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rable and reliable as it is on conventional radiographic film, still considered as the golden standard in contemporary orthodontics.

Recently, the improvement in scanning equipment and its low cost consumer grade availability has provided an easy way of archiving the cephalograms.[9] But are these scanned images accurate enough to be adopted as an efficient alternative to conventional films and manual tracing?, is the question that may limit the use of scanned images and cephalometric softwares.[10,11] In Pakistan, although many aspects relating to cephalometric radiography have been studied, digital cephalometry and cephalometric analysis software has received little attention.[12] The aim of this study was to compare angular cephalometric analysis performed via the classic method of manual tracing with a computerized method using a cephalometric software (Viewbox 4.0™), where the lateral cephalograms were scanned and then digitized onscreen.

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 angular measurements commonly used in the orthodontic department of IIDH were obtained with the help of a standard protractor. 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. 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-

TABLE 1:LANDMARKS TO BE IDENTIFIED IN THIS STUDY

N:	Nasion	A:	A point
S:	Sella	ANS:	Anterior nasal spine
Me:	Menton	PNS:	Posterior nasal spine
Go:	Gonion	UIA:	Upper incisor apex
Pog:	Pogonion	UIE:	Upper incisor edge
B:	B point	LIA:	Lower incisor apex
Sn:	Subnasale	LIE:	Lower incisor edge

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

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
SN-PP	Angle formed between SN and palatal planes (Ans-Pns)
MMA	Angle formed between palatal and mandibular plane
IMPA	Angle formed by the intersection of the mandibular incisor axis to the mandibular plane
Interincisal	Angle formed by the intersection of the mandibular incisor axis to the maxillary incisor axis
Nasolabial	Angle determined by points collumella, Sn, and ULM

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

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 angular measurements between the manually traced and scanned lateral cephalograms. Accuracy was defined as concordance of the digitally obtained angular measurements with the manually calculated angular 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

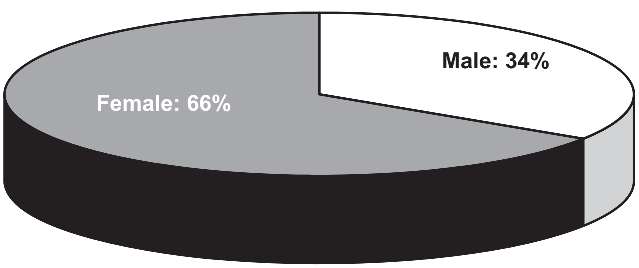

Fig 1: Gender Distribution

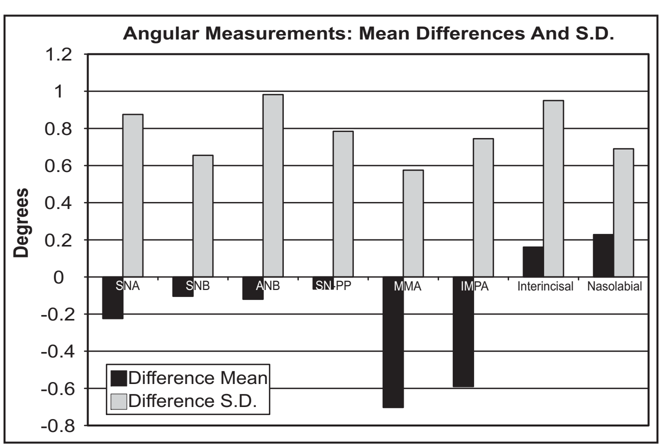

Fig 2: Angular Measurements: Mean Differences and Standard Deviations

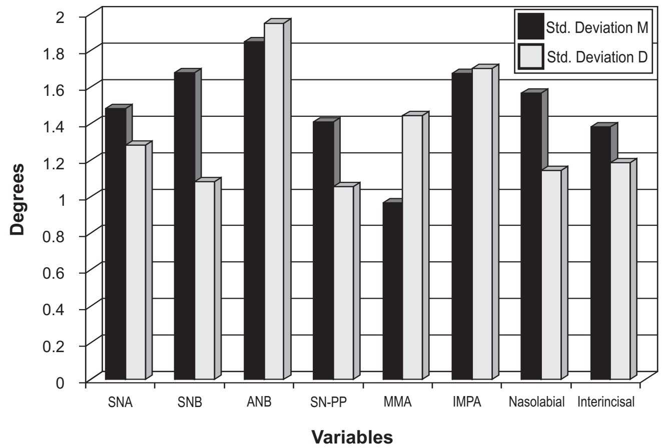

Fig 3: Intra Operator Reliability: Angular Measurements Standard Deviations

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"2º difference for any angle between the manual and digital method as proposed by McClure et al.[13]

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).

Means and standard deviations for the 8 angular measurements are presented in the table 4. The data was subjected to paired student t test with 95% confidence interval. Statistically significant differences were found in 4 out of 8 measurements. The difference was highly significant for SNA, MMA, IMPA and Nasolabial angles (p d" 0.006). The interincisal and SNB angles showed p values close to our threshold (p = 0.066 and 0.084 respectively). Highest mean difference was observed for angle MMA (-.703).

All angular measurements displayed strong correlations (r > .75). ANB showed the lowest r values for both methods (r = .852 for manual and r =.799 for digital). Standard deviations of the mean differences

TABLE 4: COMPARISON OF ANGULAR MEASUREMENTS

	Manual		Digital		Difference		Sig.
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
SNA	79.967	3.577	80.191	3.433	-.224	.875	.006
SNB	76.338	3.820	76.443	3.819	-.104	.655	.084
ANB	3.628	3.280	3.748	3.264	-.120	.982	.183
SN-PP	8.942	3.525	9.007	3.484	-.065	.784	.365
MMA	24.263	6.923	24.966	6.937	-.703	.575	.000
IMPA	95.500	9.086	96.090	9.138	-.590	.745	.000
Interincisal	120.483	15.857	120.323	15.919	.161	.950	.066
Nasolabial	97.940	13.630	97.712	13.704	.228	.690	.000

TABLE 5: CORRELATION OF INTRA-OPERATOR ANGULAR MEASURMENTS

Angular Measurements	Mean Difference		Std. Deviation		Correlation	
	M	D	M	D	M	D
SNA	-.495	-.380	1.482	1.284	.912	.924
SNB	-.325	-.075	1.680	1.082	.914	.964
ANB	-.170	-.305	1.847	1.951	.852	.799
SN-PP	.250	.445	1.410	1.054	.900	.943
MMA	-.400	-.240	.968	1.443	.984	.967
IMPA	.100	-.475	1.675	1.704	.982	.979
Nasolabial	-.425	-.485	1.567	1.145	.994	.997
Interincisal	.100	-.265	1.382	1.186	.997	.997

were lower for all digital measurements except for MMA, ANB and IMPA (Table 5). Highest standard deviations were observed for angle ANB in both methods (SD = 1.847 for manual and SD = 1.951 for digital)

DISCUSSION

The purpose of this investigation was to assess the accuracy of the angular cephalometric measurements on scanned lateral cephalograms with the help of a computer software. The results of the fiducial measurements indicated a distortion of 0.4% in both horizontal and vertical dimensions for the scanning process, which was corrected when the image was imported into the Viewbox Software.

In our study, 4 out of 8 angular measurements showed statistically significant differences, when digital and conventional methods were compared. 2 of those measurements involved landmark Gonion (MMA and IMPA angles). This is probably because of the uncertainty in locating Gonion on digital images, as there was no provision in the software for bisection of the angle formed by ramal and anatomical mandibular plane, and its intersection on the posterior border of the angle of the mandible. This affected all the measurements related to the mandibular plane, which in our study was on the line joining Menton and Gonion. The landmark identification errors inherent at Go in patterns of distribution result in limited reliability of the mandibular plane as a cephalometric structure. The error at landmark Me is reported to be within the acceptable range to be considered precise, with a dominantly horizontal pattern of error, casting minimal error in angular measurements.[14] This phenomenon could be explained by 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 mandibular plane as unreliable as compared to other cephalometric planes such as S-N. The error at Go for both film and digital identification methods has been reported to be well beyond that which could be considered precise. McClure[15] observed that “the magnitude of error seen at Go, as well as the distribution of error at Go, call into question the reliability of mandibular plane as an infinitely reliable reference plane" commonly used to determine the vertical orientation of the mandible in relation to the remainder of the craniofacial complex. Our study supports the fact that magnitude of error at Go is more than at any other landmark studied.

Results in this study also indicated significant difference for IMPA angle which relates the lower incisal long axis to mandibular plane. This can partly be explained by the uncertainty in locating the lower incisor apex on the film or image. The error at lower incisor apex (LIA) has been reported to be beyond the accepted range of precision for both film and digital along the y-axis and just within this range for the x-axis in both methods.[16] Stabrun and Danielsen[17] concluded that the lack of certainty in locating the LIA should be taken in to account when using the axial inclination of the lower incisor in diagnosis and treatment planning. Our results also concur that caution should be exercised in relying too heavily on the axial inclination of the lower incisor alone in diagnosis and treatment planning decisions.

The other angles showing significant differences in digital vs. conventional method were SNA and Nasolabial. SNA difference can be explained by the difficulty in accurately identifying the A point. This point is frequently obscured by prominent cheeks, and rare earth intensifying screens for enhancement of soft tissue visualization usually makes it further difficult to locate it accurately.[18] Many researchers have proposed alternatives to A point for the relative position of the maxilla to the cranial base for similar reason. Similarly, the nasolabial angle depends on landmarks that are placed on a curve with wide radii which show proportionally greater errors of measurement, regardless of the method used. This difficulty reflected in the significant difference found in our results. Baumrind[19] noted that the geometric form of the error distribution around a landmark is reflected by the definition of the landmark, that a point situated on a curvature such as Subnasale (Sn) is relatively well defined in one direction or axis, whereas its other axis is more uncertain. Thus, he observed, the cephalometric variables display a varying degree of measurement error, depending on how the lines, constituting the linear or angular variable, intersect the reference points. This principle was evident in our study with landmarks Go and Sn, the angles on which showed less accuracy.

It is difficult to define accuracy in cephalometrics, considering the amount of landmark identification error inherent in the technique. Our method relied on considering the manually traced conventional cephalogram as a gold standard, and then comparison was made among the groups. Although some researchers have applied more strict criteria as 1 degree or 1 mm to declare a reading as accurate[20], Gregston et al[21] and McClure[13] believe that "a difference of 2° or 2mm in means does not appear to cause a clinical difference in classification or treatment decisions in most of the parameters." 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.

Digitizing the radiographs using a scanner offers many advantages.; image storage and archiving is simplified; the digital image can be displayed on the computer screen and can be magnified, manipulated, and enhanced for easier and clearer viewing; the image can be transmitted over the internet without any loss of quality; digital radiographs can be archived avoiding damage of x-ray film.[22] Despite so many advantages that this process provides, it is computer and scanner dependent, needs additional software, and is more expensive. The file size is large and requires considerable storage space. Similar to learning to manually trace a cephalometric radiograph, there is a learning process required to use cephalometric software.[15] The expansion to computer-based programs continues the direction of dental practice into the world of technology. Scanning of radiographs is one of the ways to capture the records taken during past decades. It would seem as if this transition phase will soon be over and conventional cephalometry will be replaced with digital cephalometric systems for quicker, clearer and better digital image acquisition.

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 angular cephalometric analysis.

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