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A comparison of cephalometric measurements: a picture archiving and communication system versus the hand-tracing method—a preliminary study

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SUMMARY Traditionally, cephalometric analysis has been carried out using a hand-tracing manual method. In imaging, picture archiving and communication systems (PACS) are information management systems used for the capture and measurement of medical and dental radiographs. Although not customized for lateral cephalometry, this study aimed to evaluate the cephalometric measurements made on screen using PACS compared with the conventional hand-tracing method. Six angular and four liner parameters were measured on five radiographs of four females and one male with an age range of 14–20 years. Analysis was completed using the Wilcoxon rank-sum test.

For the electronic method, SNB ($P=0.04$) and lower incisor angle ($P=0.05$) were the only parameters found to be significantly different between the two operators. There was no significant difference between operators 1 and 2 for the hand-tracing method for any measurement. All measurements were comparable between the two methods.

This preliminary study would suggest that using PACS may be an acceptable method for obtaining cephalometric measurements for treatment planning; however, further evaluation is necessary with a larger sample size.

Introduction

Lateral cephalometric radiographs have been used for many years to assist with orthodontic diagnosis, treatment planning, and treatment progress. Traditionally, cephalometric analysis has been carried out using a manual method. An acetate sheet is placed over the radiograph and measurements are recorded of the distances and angles between cephalometric landmarks with a ruler and a protractor. The diagnostic value of such analyses depends on the accurate identification of clearly defined landmarks on cephalograms (Baumrind and Frantz, 1971a,b). Other errors are caused by image acquisition, which is dependent on the errors during exposure of the radiographs, and measurement error, which is due to faulty measuring devices or the technique itself (Baumrind and Frantz, 1971b).

Rapid advances in computer technology have allowed electronic methods to be developed. Commercially available electronic digitizing apparatus has allowed mathematical calculations of angles and distances from the digitization of landmarks and has the advantage of considerable time saving compared with manual hand tracing (Uysal *et al.*, 2009). Digital systems also eliminate chemical and associated environmental hazards, the images are easy to store, and communication between providers is facilitated (Quintero *et al.*, 1999; Brennan, 2002).

While discrepancies have been found between hand-tracing and digital methods, any differences have been minimal (Chen *et al.*, 2000) and considered clinically acceptable (Geelen *et al.*, 1998; Roden-Johnson *et al.*, 2008; Naoumova and Lindman, 2009; Polat-Ozsoy *et al.*, 2009).

In imaging, picture archiving and communication systems (PACS) are computers dedicated to the storage, measurement, distribution, and presentation of images. One such system is the Impax Enterprise Solution (Agfa HealthCare, Mortsel, Belgium), a digital image and information management system used for the capture of medical and dental radiographs, including lateral cephalograms. These PACS allow radiographs to be viewed on a display monitor and linear and angular measurements are made using tools available in the software program.

In the current technological age, given the advantages of digital imaging, more and more clinical settings are likely to switch from conventional film radiography to digital systems (Quintero *et al.*, 1999). These systems will often be accompanied by PACS viewing software and if the measurement tools are reliable, there would be less need for a customized cephalometric tracing program.

The use of PACS to measure distances in hip fracture patients (Johnson *et al.*, 2008) and of tumour masses (Monsky, 2004) has been shown to be both accurate and reproducible. To date, there are no studies investigating the use of PACS for lateral cephalometric measurements.

Therefore, the aim of this research was to perform a preliminary study to evaluate inter-examiner reproducibility

of angular and linear lateral cephalometric measurements made on screen using PACS compared with the conventional hand-tracing method. The null hypothesis tested is that there is no difference in any of the measurements between the two operators and the two methods.

Materials and method

Five prospective lateral cephalograms were taken from consecutively attending patients to a new consultation clinic using a Proline PM 2002 CC (Planmeca, Helsinki, Finland). Four of these were females and one was male, with an age range of 14–20 years. All subjects were positioned in the cephalostat with the sagittal plane at right angles to the path of the X-rays and the Frankfort plane parallel to the floor. The subjects were asked to place their teeth in centric occlusion. An Agfa CR MD4.0 general imaging plate (Agfa HealthCare) was used and processed in the Agfa CR 25.0 digitizer (Agfa HealthCare), with a resolution of 20 pixels/mm.

The images were viewed on a computer monitor (1024 × 768 pixels) using Impax ES Agfa Web 1000 5.1 software (Agfa HealthCare). The tools within the program were used to record linear distances (to 0.1 mm) and angular measurements (to 0.1 degrees). The software does not readily permit the outline tracing of landmarks and therefore a line of best fit was used. Image enhancements, including brightness, contrast, and magnification, were used as required.

For the hand-tracing method, the films were printed using the Agfa Drystar 4500 on to Agfa Drystar DT1 B media (8 × 10 inches) film (Agfa HealthCare UK, Brentford, Middlesex, UK). Hand tracings were performed using a standardized light viewing box and a 0.5 mm HB pencil on cephalometric tracing film acetate (8 × 10 inches; 3M Unitek, Monrovia, California, USA). Linear and angular measurements were made with the aid of a cephalometric protractor (Orthopli Corporation, Philadelphia, Pennsylvania, USA).

Seven angular and four linear parameters (Figure 1) were recorded by the two authors for each lateral cephalogram using the computer software program and the hand-tracing method. Both operators had at least 4 years' experience of the hand-tracing method and at least 1 year's experience of the electronic method. Instructions were given regarding the location of the landmarks and the measurements required. Both authors remeasured each lateral cephalogram using both methods after a 4 week interval.

Statistical analysis

The data were entered into the Statistical Package for Social Sciences, Version 17.0 (SPSS Inc., Chicago, Illinois, USA) for analysis. Non-parametric tests were used due to the small sample size. Paired-sample Wilcoxon signed-rank tests were used to assess intra-examiner error and no differences were found between the initial measurements and those taken 4 weeks later. Wilcoxon rank-sum tests were used to assess the differences between cephalometric measurements made on screen using PACS compared with the conventional hand-tracing method. The differences between Operators 1 and 2 were also analysed. The significance level was set at 0.05.

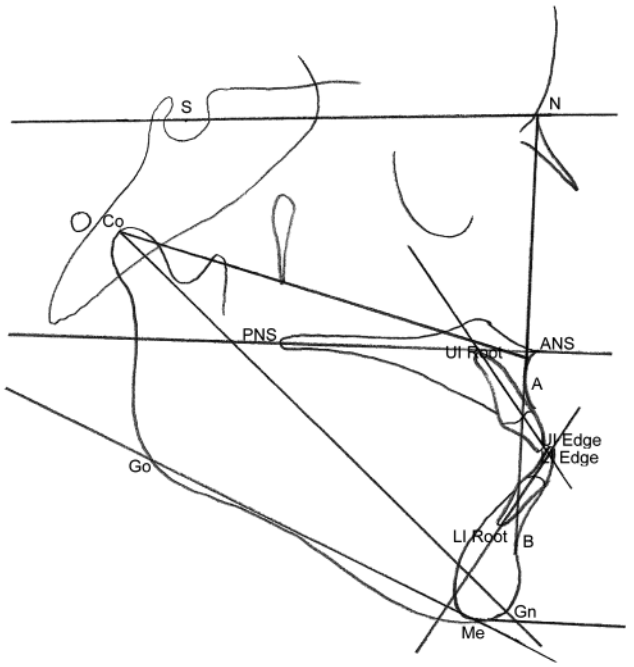

Figure 1 Description of the measurements used in the study. SNA: angle between points S, N, and A; SNB: angle between points S, N, and B; ANB: angle between points A, N, and B; MMPA: angle between the maxillary plane (ANS to PNS) and the mandibular plane (Go to Me); UFH: linear measurement from N to ANS with the Frankfort plane horizontal; LFH: linear measurement from ANS to Me with the Frankfort plane horizontal; UI: angle between the upper incisor long axis (UI edge to UI root) and the maxillary plane; LI: angle between the lower incisor long axis (LI edge to LI root) and the mandibular plane; II: angle formed the upper incisor long axis and the lower incisor long axis; MAX: linear measurement from Co to the inferior surface of ANS where it is 2 mm thick; MAND: linear measurement from Co to Gn.

Results

Descriptive statistics for both operators and both methods are presented in Table 1. The measurements of operator 1 were compared with those of operator 2 for the electronic and hand-tracing methods (Table 2). For the electronic method, SNB ($P=0.04$) and lower incisor (LI) angle ($P=0.05$) were found to be significantly different between the two operators. There was no significant difference between operators 1 and 2 for the hand-tracing method for any of the measurements.

Electronic tracing measurements were compared with those for hand tracings between operators 1 and 2 (Table 3). None of the variables were significant for either of the operators.

When comparing operator 1 with operator 2, the null hypothesis was accepted for all measurements using the hand-tracing method and all but SNB and LI for the

Table 1 Descriptive statistics for operators 1 and 2 for electronic tracing and hand-tracing methods.

		Electronic method			Hand method		
Parameter	Operator	Median	Minimum	Maximum	Median	Minimum	Maximum
SNA (°)	1	77.5	70	90	80.5	76	91
	2	80.0	75	99	79.5	77	90
SNB (°)	1	81.5	79	87	83.5	80	89
	2	84.0	79	89	82.0	80	88
ANB (°)	1	−3.0	−5	9	−4.0	−8	8
	2	−3.5	−8	10	−3.0	−5	8
MMPA (°)	1	24.0	19	35	22.5	19	33
	2	25.0	19	39	22.5	18	32
UFH (mm)	1	54.0	46	62	53.5	46	62
	2	54.0	46	62	55.5	49	66
LFH (mm)	1	67.0	63	94	65.5	63	94
	2	65.0	61	93	67.0	62	92
UI (°)	1	118.5	116	132	118.0	111	130
	2	122.0	115	136	120.0	113	130
LI (°)	1	84.5	78	100	87.0	74	98
	2	92.5	86	104	88.0	80	104
II (°)	1	134.0	109	141	133.0	108	143
	2	119.0	96	133	130.0	107	136
MAX (mm)	1	96.5	88	106	98.5	86	109
	2	95.5	82	103	93.0	83	105
MAND (mm)	1	122.5	115	152	122.0	115	149
	2	129.0	117	158	125.0	119	155

Table 2 Operator 1 versus operator 2 for the electronic tracing and hand-tracing methods.

		Electronic method		Hand method	
Parameter	Operator	Mean ranks	*P* value	Mean ranks	*P* value
SNA (°)	1	8.95	NS	10.55	NS
	2	12.05		10.45	
SNB (°)	1	7.75	*	12.20	NS
	2	13.25		8.80	
ANB (°)	1	10.80	NS	8.75	NS
	2	10.20		12.25	
MMPA (°)	1	9.70	NS	10.70	NS
	2	11.30		10.30	
UFH (mm)	1	10.95	NS	8.80	NS
	2	10.05		12.20	
LFH (mm)	1	11.45	NS	10.30	NS
	2	9.55		10.70	
UI (°)	1	9.65	NS	9.45	NS
	2	11.35		11.45	
LI (°)	1	8.00	*	9.40	NS
	2	13.00		11.60	
II (°)	1	12.65	NS	12.10	NS
	2	8.35		8.90	
MAX (mm)	1	11.10	NS	11.95	NS
	2	9.90		9.05	
MAND (mm)	1	8.25	NS	8.85	NS
	2	12.75		12.15	

NS, non-significant.
*$P<0.05$.

Table 3 Electronic tracing versus hand-tracing methods for operators 1 and 2.

		Operator 1		Operator 2	
Parameter	Method	Mean ranks	*P* value	Mean ranks	*P* value
SNA (°)	Electronic	8.80	NS	10.60	NS
	Hand	12.20		10.40	
SNB (°)	Electronic	8.10	NS	12.70	NS
	Hand	12.90		8.30	
ANB (°)	Electronic	11.95	NS	9.80	NS
	Hand	9.05		11.20	
MMPA (°)	Electronic	11.15	NS	11.75	NS
	Hand	9.85		9.25	
UFH (mm)	Electronic	11.05	NS	8.80	NS
	Hand	9.95		12.20	
LFH (mm)	Electronic	11.65	NS	10.60	NS
	Hand	9.35		10.40	
UI (°)	Electronic	11.75	NS	12.45	NS
	Hand	9.25		8.55	
LI (°)	Electronic	10.50	NS	11.90	NS
	Hand	10.50		9.10	
II (°)	Electronic	10.00	NS	8.70	NS
	Hand	11.00		12.30	
MAX (mm)	Electronic	9.55	NS	10.20	NS
	Hand	11.45		10.80	
MAND (mm)	Electronic	10.60	NS	11.75	NS
	Hand	10.40		9.25	

NS, non-significant.

electronic method. The null hypothesis was accepted for both operators when the electronic method was compared with the hand-tracing method for all measurements.

Discussion

Digital imaging offers several advantages over conventional radiography including faster processing, easy storage, retrieval,

and image enhancement (Dvortsin *et al.*, 2008). In previous studies (Geelen *et al.*, 1998; Chen *et al.*, 2000; Roden-Johnson *et al.*, 2008; Naoumova and Lindman, 2009; Polat-Ozsoy *et al.*, 2009), the differences between electronic and hand-tracing methods for cephalometric measurements were found to be clinically acceptable. However, these electronic methods included customized cephalometric software programs. In the present study, PACS, a general radiographic display and measurement program, was used. This is not customized for cephalometry, so the measurements that were made used the tools available in the software program.

When the hand-tracing method was investigated, no differences was found between Operators 1 and 2 for any variable. The reliability of hand tracing has been well demonstrated in previous studies (Naoumova and Lindman, 2009) and the results were consistent with the findings of other authors.

The electronic method showed the value for SNB and LI to be statistically significantly different between the two operators; however, no significant differences were found for any of the other variables. Operator 1 recorded lower SNB and LI values.

Other authors have noted significant differences for SNB when comparing digital and hand-tracing methods (Polat-Ozsoy *et al.*, 2009); however, not all studies have found this to be the case (Celik *et al.*, 2009). A larger sample size may well have given a non-significant result.

The lower incisor is difficult to locate, in particular, lower incisor apex (Baumrind and Frantz, 1971a,b; Oliver, 1991; Chen *et al.*, 2000; Polat-Ozsoy *et al.*, 2009). The difficulty in constructing reference planes when using software programs may explain why variables requiring constructed planes are difficult to record consistently (Geelen *et al.*, 1998). In this study, the electronic method did not permit the outlining of structures such as the lower incisor. LI is dependent on the accurate depiction of the lower incisor outline and the difficulty in constructing a line through the long axis of the lower incisor may partly account for the significant result. However, it has been suggested that the digital method allows better visualization of difficult-to-locate landmarks such as incisor apices since the view is not obscured by a sheet of tracing paper (Sandler, 1988).

Both operators obtained consistent measurements when using the hand-tracing method compared with the electronic method. Operator experience has been considered an important factor in landmark identification and suggestions have been made that it may be as important as the tracing method itself (Naoumova and Lindman, 2009). Both operators in the present study had at least 1 year's experience of the electronic method and considerably more using the hand-tracing method.

This preliminary study used only five lateral cephalograms which is too small a sample size to draw definitive conclusions. To ensure freedom from error, there is a need to evaluate software programs using a larger sample size (Celik *et al.*, 2009).

Conclusion

Using a limited sample of five lateral cephalograms, no significant differences were found for the conventional hand-tracing method between the two operators. When using PACS, differences were found only for SNB and LI between the two operators. Both operators obtained similar measurements for the hand-tracing and the electronic tracing methods for all variables. The findings of this preliminary study would suggest that using PACS may be an acceptable method for defining cephalometric measurements for treatment planning; however, further evaluation is necessary with a larger sample size.

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