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Validity and reproducibility of cephalometric measurements obtained from digital photographs of analogue headfilms

Simonas Grybauskas, Irena Balciuniene, Janis Vetra

SUMMARY

The emerging market of digital cephalographs and computerized cephalometry is overwhelming the need to examine the advantages and drawbacks of manual cephalometry, meanwhile, small offices continue to benefit from the economic efficacy and ease of use of analogue cephalograms. The use of modern cephalometric software requires import of digital cephalograms or digital capture of analogue data: scanning and digital photography. The validity of digital photographs of analogue headfilms rather than original headfilms in clinical practice has not been well established. Digital photography could be a fast and inexpensive method of digital capture of analogue cephalograms for use in digital cephalometry. AIM. The objective of this study was to determine the validity and reproducibility of measurements obtained from digital photographs of analogue headfilms in lateral cephalometry. MATERIAL AND METHODS. Analogue cephalometric radiographs were performed on 15 human dry skulls. Each of them was traced on acetate paper and photographed three times independently. Acetate tracings and digital photographs were digitized and analyzed in cephalometric software. Linear regression model, paired t-test intergroup analysis and coefficient of repeatability were used to assess validity and reproducibility for 63 angular, linear and derivative measurements. RESULTS AND CONCLUSIONS. 54 out of 63 measurements were determined to have clinically acceptable reproducibility in the acetate tracing group as well as 46 out of 63 in the digital photography group. The worst reproducibility was determined for measurements dependent on landmarks of incisors and poorly defined outlines, majority of them being angular measurements. Validity was acceptable for all measurements, and although statistically significant differences between methods existed for as many as 15 parameters, they appeared to be clinically insignificant being smaller than 1 unit of measurement. Validity was acceptable for 59 of 63 measurements obtained from digital photographs, substantiating the use of digital photography for headfilm capture and computer-aided cephalometric analysis.

Key words: cephalometry, reproducibility, dry skull, acetate tracing, digital photography.

INTRODUCTION

Variety of emerging computer software for lateral cephalometry in clinical orthodontics simplified the analysis and reduced time needed to perform certain measurements [1,2,3]. The ease of use and ability to perform several analyses at a time as well as convenience in generation of treatment predictions have contributed to a shift from manual tracing on acetate paper towards digital computer-aided cephalometry [4]. Digital cephalometry has offered even more advantages, i.e., option to manipulate the image for size and contrast, image enhancement, ability to archive and improve access to images, superimposition of images [5]. Moreover, patients benefit from reduced dose of radiation if a digital cephalograph is chosen for image capture, whereas the lack of user-sensitive chemical development process and instantaneous image formation save both space and time in the clinician's practice [6].

By now, many offices have not yet switched to the use of digital cephalographs, therefore the digiti-

[1]*Institute of Odontology, Faculty of Medicine, Vilnius University, Vilnius, Lithuania*
[2]*Institute of Anatomy and Anthropology, Riga Stradins University, Riga, Latvia*

Simonas Grybauskas[1] *– D.D.S., MOS RCSEd*
Irena Balciuniene[1] *– D.D.S., PhD, Dr. habil. med., prof.*
Janis Vetra[2] *– M.D., Dr.habil.med., prof.*

Address correspondence to Dr. Simonas Grybauskas, Institute of Odontology, Faculty of Medicine, Vilnius University, Zalgirio 115, Vilnius LT-08217, Lithuania.
E-mail: simonas.grybauskas@gmail.com

zation process of analogue head films is the only option if the benefits of digital cephalometric analysis are anticipated. The two known methods of headfilm capture are scanning and digital photography. Studies have shown that images captured from flatbed scanner can be reliable as compared to their corresponding analogue headfilms for use in clinical practice, not so good for research [7-11]. Little data exists on the reliability of images captured by means of digital photography – a poorly documented operator-sensitive technique with some speculations on distortion of images [12]. Computer-aided cephalometry and digitizing process of analogue headfilms were reported by numerous authors [2,8,12-21]. However, results of comparison of digitizing methods with analogue measurement methods were contradictory [2,9,14,18,22,23].

The aim of this study was to evaluate validity and reproducibility of measurements obtained from digital photographs of headfilms as compared to those obtained from traditional acetate paper tracings. Validation of digital photography can enable its use in digital capture of analogue data for computer-aided cephalometric analysis without need for specific hardware.

MATERIAL AND METHODS

A set of 15 human dry skulls was obtained from the Department of Anatomy, Histology and Anthropology at Vilnius University. The skulls were chosen according to following criteria: occlusion was stable and reproducible with at least three pairs of antagonist teeth; posterior occlusal height was present; at least one of the condyles was intact and fit into glenoid fossa.

The mandible part was related to the maxilla of its couterpart skull on the basis of occlusal interdigitation or maximal contact, and condylar seating in the glenoid fossa. Since soft tissue components of the temporomandibular joint (TMJ) were missing on dry skulls, interpositional items were used to support the condyles in the center of the glenoid fossa preventing them from contact with the bone surface, thus, mimicking natural intra-articular space. Subsequently, the mandible was secured in this position with scotch tape around the skull. Fifteen lateral cephalograms were performed on the series of skulls by securing skulls in the cephalostat (Moviplan 8000 CE, Villa Sistemi Medicali, Italy) with the ear rods in the external auditory meati, and the distance between film and midsagittal plane at 13 cm. Preliminary work led to using the following radiographic setting: 77 kVp, 12 mA, 0.10 s.

Headfilms were traced on acetate paper for three times with one week interval between independent tracings by the same operator, hence, the acetate tracing group was composed of 45 cephalometric acetate tracings. Two ruler points were marked on every tracing 108 mm apart. Following this, headfilms stayed on the view box and 15 digital pictures were taken (Canon 350D, Macro lens 100mm f2.8; 5Mp resolution, image resolution 3200 x 2400 pixels) at a right angle from a distance of 2 meters. A transparent ruler of 108 mm was present on the radiograph whereas the camera was secured on the tripod when taking pictures of every radiograph. Three pictures were taken for every headfilm and the camera was dismounted and remounted after every picture to immitate independent attempts. The digital photography group was composed of 45 digital photographs of lateral headfilms.

Digital pictures were imported into Dolphin 9.0 cephalometric software (Doplhin Imaging, USA) and digitizing procedure was performed on the series of 15 triplets of digital pictures. Images were sharpened, saturated, contrasted and brightened if needed to achieve best visibility of landmarks. Acetate tracings were stuck to the computer screen (hardware: IBM T60p, 1.8GHz, 2GB RAM, ATI Mobility FireGL V5200, screen resolution 1600x1200 dpi, 32bit color quality) with scotch tape and identical digitizing procedure was performed on every tracing. The magnification factor was known to be 1.08 for the given cephalograph, therefore, 108 mm distance between ruler points was attributed to 100 mm distance on the software.

The error was inherent in landmark identification process and was known to be variable depending upon the clarity of nature and definition of landmarks [9]. Hand measuring was abandoned in this study. Instead, once the digitizing procedures were finished for the 3 sets of acetate tracings and 3 sets of digital photographs, software generated 6 sets of linear and angular measurements that were exported and used to assess reproducibility and validity of digital photographs of headfilms (Table 1). Since measurements were generated in automatic fashion by the software, no measuring errors were introduced in this part of the study. Data was imported and statistical analysis processed with SPSS 15.0.

Assessment of reproducibility. Bland and Altman's formula (1999) was used for the statistical analysis of reproducibility to determine coefficient of repeatability of every measurement for two different methods ($R = \sqrt{\frac{1}{n-1} \times \sum_{i=1}^{n} v_i \times s_{i^2}}$) [24].

Measurements were ranked as reproducible if both R coefficient and standard deviation (SD) of differences from the average values were less than 1 unit of measurement.

One "unit of measurement" in this study was an equivalent of one millimeter, one degree or one percent. It was used as a substitute in order to avoid repetition of bulky explanations of reproducibility for linear angular and derivative measurements. The estimated reproducibility in this study was classified into four groups: ultra high reproducibility of measurements (R value and SD of differences smaller than 0.5 units), high reproducibility (R and SD of differences greater than 0.5 unit but smaller than 1 unit), moderate reproducibility (R value and SD of differences are between 1 and 2 units), and poor reproducibility (R value and SD of differences greater than 2 units). Mean of difference is twice the mean of differences from the average, therefore the limit of 2 units for R value was considered to be the range of clinical acceptance. All differences were taken for absolute numbers in this study.

Assessment of validity. Validity was rated as acceptable or non-acceptable in this study. Validity of measurements obtained from digital photographs were considered to be acceptable provided both of the two following conditions were met: first, paired t-test analysis revealed no statistically significant intergroup difference (P>0.05) that would also be clinically significant (both mean and SD of differences greater than 2 units) between measurements obtained from digital photographs and those obtained from acetate tracings. Second, linear regression analysis showed strong correlation between methods: the intraclass correlation coefficient r>0.75

$$(r = \frac{\mathrm{var}(skull)}{\mathrm{var}(skull) + \mathrm{var}(method) + \mathrm{var}(error)});$$

standardized beta coefficient >0.7 and confidence intervals for beta contained value 1; there was no systematic offset in values and confidence intervals for alpha contained 0 value. The use of linear regression was essential in testing the agreement between two series of paired measurements that were shown to have few statistically significant differences between means, nevertheless, could have poor agreement [25]. Acetate tracing was the independent method, whereas digital photography was a dependent cephalometry method in linear regression model.

RESULTS

Reproducibility of measurements obtained from acetate tracings

Fifteen (23.81%) out of 63 measurements used in lateral cephalometry were highly reproducible, with the standard deviation (SD) of differences of measurements being less than 0.5 unit (one unit equals one millimeter, one degree or one percent). Eight of them (12.70%) were characterized by ultra small R coefficient (<0.5 unit) whereas 7 measurements by a small R value (0.5-1 of a unit). Thirty two (50,79%) measurements fell into moderate level of R value and SD of differences of 1 unit, 8 measurements demonstrated SD lower than one unit with R exceeding one unit. Nine (14.29%) parameters demonstrated both R and SD of differences being beyond 2 units of measurement.

Reproducibility of measurements obtained from digital photographs of headfilms

Eleven (17.46%) out of 63 measurements used in digital photography group were characterized by ultra high reproducibility with both R value and SD of differences being smaller than 0.5 of a unit of measurement. Twenty seven (42.86%) of 63 measurements showed high reproducibility with both R coefficient and SD of differences being smaller than 1 unit, 8 more measurements demonstrated SD lower than 1 unit, however R values were higher than 2 units. Seventeen (26.98%) of 63 measurements showed R values greater than 2 units, and four (6.35%) of them were characterized by SD of differences greater than 2 units. Overall characteristics of least reproducible measurements is presented in Table 2.

Validity of measurements obtained from digital photographs of lateral headfilms

Validity was acceptable for all measurements except LI/Occ, S-Go, UFH/TFH and N-ANS (Table 3). There was a high correlation between methods for 59 out of 63 measurements: linear regression model showed interclass correlation coefficient r>0.8; standardized coefficient Beta>0.9; confidence intervals for Alpha and Beta values contained values 1 and 0 respectively. Non-acceptable validity was determined for 4 measurements: LI/OC, S-Go, UFH/TFH and N-ANS. In 60 out of 63 lateral cephalometric measurements differences between the two methods were less than 0.5 units and less than 1 unit in the rest three measurements. There were no statistically significant differences between measurements obtained from digital photographs of lateral headfilms and corresponding acetate cephalometric tracings in 49 measures. A list of measurements for which paired t-test analysis and linear regression analysis showed statistically significant differences or poor correlation between the two methods is presented in Table 3.

Table 1. Linear, angular and derivative measurements used for cephalometric analysis

Measurement	Definition
Cranial base dimensions	
Linear measurements	
S-N	Anterior cranial base length
S-Ar	Distance between sella and articulare
S-Ba	Posterior cranial base length
Ba-N	Total cranial base length
Angular measurements	
N/S/Ar	Angle between S-N and S-Ar lines
N/S/Ba	Cranial base saddle angle between S-N and S-Ba
SN/FH	Angle determined by S-N and Frankfort horizontal (FH) plane
Facial height	
Linear measurements	
ANS-N	UAFH, upper anterior facial height
ANS-Me	LAFH, lower anterior facial height
N-Me	TAFH, total anterior facial height
LAFH/TAFH	Ratio of lower anterior face height to total anterior face height
UAFH/LAFH	Ratio of upper facial height to lower facial height
S-Go	TPFH, total posterior face height
S-PNS	Posterior midfacial height
Ar-Go	Lower posterior facial height
Jarabak ratio	Ratio of total posterior to total anterior face height
Vertical relationship	
Angular measurements	
SN/PP	Angle determined by SN and Palatal plane
SN/MP	Angle determined by SN and Mandibular plane
SN/OP	Angle determined by SN and Occlusal plane
FH/PP	Angle between FH and Palatal plane
FH/MP	Angle determined by FH and Mandibular plane
FH/OP	Angle determined by FH and Occlusal plane
MP/PP	Angle determined by Mandibular and Palatal planes
PP/OP	Angle determined by Palatal and Occlusal planes
Relationship of the maxilla to the cranial base	
Linear measurements	
A-Nv	Distance from point A to Nv line
Co-A	Distance from Condylion to A point
Ar-A	Distance from Articulare to A point
Ba-A	Basialveolar length
A-NPog	Distance from point A to facial plane line
Angular measurements	
S/N/A	Angle determined by S-N and N-A lines
NA/FH	Angle determined by N-A line and FH plane
Relationship of the mandible to the cranial base	
Linear measurements	
B-Nv	Distance from point B to Nv line
Angular measurements	
S/N/B	Angle determined by S-N and N-B lines
S/N/Pog	Facial angle determined between S-N and facial plane lines
FH/NPog	Facial angle determined between FH plane and facial plane linbe
N/S/Gn	Y-axis, the angle determined by S-N and S-Gn lines
S/Ar/Go	Articulare angle, determined by S-Ar and Ar-Go lines
Relationship of the maxilla to the mandible	
Linear measurements	
Wit's upraisal	Distance between the projections of point A and B onto occlusal plane
Angular measurements	
A/N/B	Angle determined by N-A and N-B lines
N/A/Pog	Convexity angle, determined by N-A and A-Pog lines
A/Ar/Gn	Angle 1 from the A-Ar-Gn triangle
A/Gn/Ar	Angle 2 from the A-Ar-Gn triangle
Ar/A/Gn	Angle 3 from the A-Ar-Gn triangle
Relationship of the maxillary dentition to the maxilla and the cranial base	
Linear measurements	
UIE-NA	Distance from Upper incisor tip to N-A line
UIE-APog	Distance from Upper incisor tip to A-Pog line
Angular measurements	
U1/NA	Angle determined by maxillary incisor axis and N-A lines
U1/FH	Angle determined by maxillary incisor axis and FH plane
U1/SN	Angle determined by maxillary incisor axis and SN line
U1/PP	Angle determined by maxillary incisor axis and Palatal plane
U1/OP	Angle determined by maxillary incisor axis and Occlusal plane
Relationship of the mandibular dentition to the mandible and the cranial base	
Linear measurements	
LIE-APog	Distance from Lower incisor tip to A-Pog line
LIE-NB	Distance from Lower incisor tip to N-B line
Angular measurements	
LI/MP	Angle determined by Mandibular incisor axis and Mandibular plane
LI/NB	Angle determined by Mandibular incisor axis and N-B line
LI/OP	Angle determined by Mandibular incisor axis and Occlucal plane
Relationship of the maxillary dentition to the mandibular dentition	
Angular measurements	
UI/LI	Angle determined by Maxillary incisor axis and Mandibular incisor axis
Maxillary or palatal dimensions	
Linear measurements	
ANS-PNS	Palatal length, distance from Anterior nasal spine to Posterior nasal spine
A-PNS	Distance from posterior nasal spine to A point
Mandibular length	
Linear measurements	
Go-Gn	Length of mandibular corpus, distance between Gonion and Gnathion points
Go-Co	Ramus height, distance between Gonion and Condilion points
Co-Gn	Length of mandibular base, distance between Condilion and Gnathion points
(Co-Gn)-(Co-A)	Maxillo-mandibular length difference – difference between Co-Gn and Co-A values
Angular measurements	
Co/Go/Gn	Gonial angle, determined by Go-Co and Go-Gn lines

DISCUSSION

In digital photography group the worst reproducibility was seen for U1/FH, U1/L1, B-Nv and articular angle (S-Ar-Go), followed by FH/OP, FH/OP, FH/NPog, UI/SN, UI/FH, UI/OP. In the acetate tracing group poor reproducibility was determined for the measurements U1/SN, U1/PP, U1/OP, U1/NA, U1/FH; L1/OP, L1/NB, L1/GoGn, U1/L1. Obviously, majority of theses measurements depend on landmarks and references of incisor teeth and poorly defined outlines or low contrast area such as Articulare, Gonion, PNS and Porion. Our data agrees with results reported by Chen et al (2000), who stated that least reliable landmarks are those that are located on curved anatomical boundaries or on axis on teeth, thus resulting in greatest inaccuracies of following measurements: U1/SN, U1/L1, L1/OP, L1/MP [9]. Our data is also in line with Baumrind and Frantz (1971a) who described "errors in identification" being specific for different landmarks and arising from inability to locate anatomical landmarks [26]. Definition was later expanded by Vincent et al (1997) who classified errors of identification caused by: poor outline of the curvature of the line upon which the landmark is positioned; contrast of the area; noise and superimposition of other structures; poor definition of the landmark [6].

In the acetate tracing group all nine measurements with poor reproducibility were angular, as well as 3 out of 4 in the analogue cephalometry group. Angular measurements showed worse reproducibility than linear measurements and it is line with studies conducted by Baumrind and Frantz as well as Savinsu et al [27,10].

The comparative analysis showed that there were few statistically significant differences between methods, however all of them were clinically insignificant with mean and SD of differences smaller than 0.5 unit, thus substantiating the use of digital photography and tracing of digital photographs in orthodontic practice. According to linear regression model, the validity of measurements obtained from digital photographs was acceptable: r>0.8, standardized beta coefficient >0.9 and confidence intervals for alpha and beta values were containing values 0 and 1 respectively ($p<0.05$) for majority of measurements (poor correlation between groups for 4 measurements needs further investigation). It is in agreement with Chen et al (2004) and Schulze et al (2002) results

Table 2. Characteristics of least reproducible measurements obtained from digitized acetate tracings and digital photographs of headfilms

Measurement	**Acetate tracing group**				**Digital photography group**			
	R value	**SD of differences**	**Confidence interval of R (95%)**		**R value**	**SD of differences**	**Confidence interval of R (95%)**	
			lower bound	**upper bound**			**lower bound**	**upper bound**
Articular Angle S-Ar-Go(°)	1.91	1.52	-1.07	4.88	***3.39***	***2.28***	-1.07	7.85
B-Nv (mm)	0.92	0.75	-0.56	2.40	***3.37***	***2.51***	-1.54	8.28
Facial Angle (FH-NPog) (°)	0.59	0.49	-0.37	1.56	***2.09***	1.56	-0.96	5.14
FH / MP (°)	1.13	0.86	-0.57	2.82	***2.25***	1.59	-0.87	5.38
FH / OP (°)	1.44	1.04	-0.61	3.49	***2.57***	1.87	-1.09	6.23
FH / PP (°)	0.78	0.61	-0.42	1.98	***2.15***	1.59	-0.97	5.26
Interincisal Angle (UI/LI) (°)	***4.40***	***4.22***	-3.87	12.67	***3.11***	***2.19***	-1.17	7.40
LI / GoGn (°)	***2.96***	***2.50***	-1.94	7.86	***2.12***	1.45	-0.73	4.97
LI / NB (°)	***2.65***	***2.43***	-2.11	7.40	1.99	1.36	-0.68	4.67
LI / Occ Plane (°)	***2.49***	***2.25***	-1.92	6.89	***2.08***	1.54	-0.94	5.10
Lower Posterior Facial Height Ratio (Ar-Go/S-Go x 100) (%)	1.63	1.35	-1.03	4.28	***2.52***	1.87	-1.15	6.19
Mandibular Body Length (Go-Gn)(mm)	***2.04***	1.65	-1.18	5.26	***2.67***	1.85	-0.97	6.30
Maxillary Depth FH / NA (°)	0.83	0.65	-0.45	2.12	***2.05***	1.54	-0.98	5.07
U1 / FH (°)	***3.32***	2.69	-1.94	8.58	***3.07***	***2.56***	-1.94	8.09
U1 / NA (°)	***3.03***	2.65	-2.16	8.22	***2.27***	1.70	-1.05	5.60
U1 / Occ Plane (°)	***2.71***	2.43	-2.05	7.48	***2.28***	1.57	-0.80	5.36
U1 / Palatal Plane (°)	***3.41***	2.68	-1.85	8.66	***2.47***	1.71	-0.87	5.82
U1 / SN (°)	***3.20***	2.70	-2.08	8.48	***2.15***	1.59	-0.98	5.27

stating that although statistically significant differences between digitized and analogue measurements existed, they were clinically insignificant [28,29]. It also agrees with the study conducted by Macri and Wenzel (1993) who stated that it was possible to achieve reliability of digital images comparable to that obtained with conventional equipment for radiographs of good quality [2]. Collins et al (2007) compared measurements from photographed lateral cephalograms and scanned cephalograms and found statistically significant differences in linear measurements by using Dolphin software [30]. Although digitalization of acetate tracings rather than scanning was used in our study, 11 out of 15 measurements that were shown to have statistically significant differences were linear measurements suggesting a need for more thorough investigation of magnification factors in computer-aided cephalometry.

Table 3. Intergroup comparison of measurements obtained from digital photographs of analogue cephalograms and corresponding acetate tracings

Measurement	Compared methods	Mean of difference	SD of difference	t	Sig. (2-tailed)	Unstandardized Coefficient Alpha	Standardized Coefficient Beta	Sig.	95% Confidence Interval for Alpha and Beta	
A-Gn-Ar (Angle 3) (°)	Dig photo	-0.09629	0.153659	2.516	***0.036***	-1.159		0.171	-2.955	0.637
	Acetate					1.023	0.999	0	0.99	1.055
Anterior Cranial Base (S-N) (mm)	Dig photo	0.31524	0.193747	-7.246	***0***	0.631		0.298	-0.697	1.958
	Acetate					0.986	1	0	0.966	1.006
Ba - A (mm)	Dig photo	0.4199	0.187261	-7.536	***0***	-0.491		0.664	-3.053	2.07
	Acetate					1.001	1	0	0.972	1.029
L1 - Occ Plane (°)	Dig photo	-0.18518	0.699007	0.828	0.432	-3.478		0.01	***-5.846***	***-1.11***
	Acetate					1.052	0.999	0	***1.019***	***1.086***
Lower Facial Height (ANS-Me) (mm)	Dig photo	0.20422	0.292465	-3.118	***0.014***	0.222		0.867	-2.803	3.247
	Acetate					0.993	0.999	0	0.947	1.04
Mandibular length (Co-Gn) (mm)	Dig photo	0.50009	0.595312	-5.551	***0.001***	-0.304		0.897	-5.638	5.03
	Acetate					0.998	0.999	0	0.953	1.044
Midfacial length Co-A (mm)	Dig photo	0.40611	0.463005	-7.176	***0***	-0.408		0.711	-2.903	2.087
	Acetate					1	0.999	0	0.971	1.029
Mx/Md diff (Co-Gn – Co-A) (mm)	Dig photo	0.22033	0.259186	-5.897	***0***	-0.338		0.39	-1.21	0.535
	Acetate					1.005	0.999	0	0.969	1.041
N - Ba (mm)	Dig photo	0.46236	0.509173	-10.128	***0***	0.255		0.757	-1.614	2.123
	Acetate					0.993	1	0	0.974	1.012
PNS-A (mm)	Dig photo	0.19733	0.274228	-3.341	***0.01***	0.63		0.539	-1.679	2.94
	Acetate					0.983	0.999	0	0.935	1.031
Posterior Cranial Base (S-Ar) (mm)	Dig photo	0.10776	0.157548	-2.981	***0.018***	-0.02877		0.943	-0.944	0.886
	Acetate					0.998	1	0	0.972	1.023
Posterior Cranial Base (S-Ba) (mm)	Dig photo	0.22644	0.255059	-7.913	***0***	-0.859		0.065	-1.786	0.068
	Acetate					1.015	1	0	0.993	1.038
Posterior Face Height (SGo) (mm)	Dig photo	0.27545	0.695934	-1.308	0.227	4.889		0.02	***1.044***	***8.734***
	Acetate					0.934	0.998	0	***0.885***	***0.983***
Saddle/Sella Angle (SN-Ar) (°)	Dig photo	-0.18889	0.271058	3.104	***0.015***	-1.045		0.544	-4.92	2.83
	Acetate					1.01	0.999	0	0.979	1.04
SN - MP (°)	Dig photo	0.24074	0.436686	-2.494	***0.037***	0.333		0.468	-0.694	1.36
	Acetate					0.979	0.999	0	0.943	1.016
Total Face Height (N-Me) (mm)	Dig photo	0.46666	0.548392	-5.93	***0***	1.395		0.385	-2.168	4.957
	Acetate					0.983	0.999	0	0.952	1.015
UFH/TFH (N-ANS:N-Me) (°)	Dig photo	0.05556	0.15411	-1.17	0.276	2.127		0.018	***0.488***	***3.767***
	Acetate					0.949	0.999	0	***0.911***	***0.987***
Upper Face Height (N-ANS) (mm)	Dig photo	0.26003	0.350888	-3.596	***0.007***	2.012		0.009	***0.671***	***3.353***
	Acetate					0.953	0.999	0	***0.925***	***0.981***

CONCLUSIONS

1. Both measurements obtained from acetate tracings and digital photographs of analogue cephalograms were shown to have adequate reproducibility with both R coefficients and SD of differences smaller than 2 units of measurement. Nine measurements in the acetate cephalometry group and seventeen in the analogue cephalometry groups failed to go within this limit and were shown to be less reproducible.

2. Majority of poorly reproducible measurements were angular or associated with least reproducible landmarks and references.

3. Validity of 59 out of 63 lateral measurements obtained from digital photographs was acceptable, thus, substantiated the use of digital photography for headfilm capture, digital tracing and computer-aided cephalometric analysis.

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