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RESEARCH ARTICLE

LATERAL PHOTOGRAPHS VERSUS LATERAL CEPHALOGRAMS: ROLE IN ASSESSMENT OF CRANIOFACIAL MORPHOLOGY

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ABSTRACT

Objective: To correlate craniofacial measurements from standardized facial photographs with analogous measurements from lateral cephalograms.
Design: A prospective cross sectional study.
Setting: A postgraduate department of Orthodontics and Dentofacial Orthopaedics based in India.
Participants: patients with no previous orthodontic or surgical treatment, no history of craniofacial trauma lateral, all six maxillary anterior teeth present, no history of craniofacial trauma and cephalograms required as a part of routine treatment records were included.
Method: The lateral cephalograms and standardised lateral profile photographs of 250 subjects (12 – 25 years) were taken with the patient in natural head position. Standard cephalometric angular and linear measurements were compared with angular and linear measurements on the photographs by identifying 8 facial landmarks. The landmarks on the face were first palpated and then marked, to ensure the position of respective skeletal landmark. Descriptive statistics for all measurements in the entire sample were computed and compared to assess Pearson correlation coefficients.
Results: The reliability of the photographic technique was satisfactory. On comparing the cephalometric and photographic variables for the entire sample, positive and significant correlations were found for all linear and angular variables studied. Highest correlations were found for ANB and ANB' (0.696, $p \leq 0.05$) and the lowest correlations were found for ML and ML'(0.575, $p \leq 0.05$).
Conclusion: Both linear and angular measurements useful for characterising facial morphology can be reliably measured from facial photographs. The photographic method was found to be repeatable, low-cost, non-invasive diagnostic alternative for epidemiologic research, provided a standardised protocol is followed.

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INTRODUCTION

In 1931Broadbent introduced cephalometrics, integrating the concept of craniometrics and radiography and since then, it has been providing important diagnostic information regarding the skeletal and the dental structures. Although lateral cephalograms are the gold standard and have become an imperative to diagnosis and treatment planning in orthodontic patients, there have been rising concerns over unnecessary exposure to radiations. The average expected dose from a lateral cephalogram is 3 μSv, which is very minor compared to the International Commission of Radiological Protection's (ICRP) recommendation that the dose limit should be 1mSv annually for the public (Graber, 1972).

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Unnecessary irradiation of patients should be avoided, since there is no threshold dose below which biologic damage does not occur. However, in a developing country, where expensive cephalometric apparatus is unavailable everywhere, photography assumes importance for diagnostic and treatment planning procedures as it is less costly and less technique sensitive. Graber (Graber, 1972) stated that the photograph assumes even greater importance when dentists do not have equipment for taking cephalograms; he considered facial photographs an essential diagnostic tool. Therefore, the possibility of predicting cephalometric values through photographs may be relevant as a non invasive diagnostic tool, especially for epidemiologic research and in conditions where expensive cephalometric apparatus may not be available readily. Although, comparisons involving cephalometric and radiographic measurements have seldom been performed, (Zhang *et al.,* 2007; Bittner and Pancherz, 1990; Staudt and Kiliaridis, 2009; De Carvalho Rosas Gomes *et al.,* 2013) conflicting results have been found. Therefore, the aims of this study were

- To focus on investigating the correlation between the sagittal and vertical craniofacial measurements obtained from standardised facial profile photographs and analogous measurements from lateral cephalograms of the same patient.
- To assess gender variations, if any, that exist in the correlation between craniofacial measurements on lateral facial photographs and lateral cephalograms

MATERIALS AND METHODS

This is a prospective, cross-sectional study which was carried out by using standardised lateral profile photographs and lateral cephalograms, taken from 250 (145 females and 105 males) patients visiting the department. The ethical approval was granted for this study by the institutional ethical committee. The patients with no previous orthodontic or surgical treatment, lateral cephalograms required as a part of routine treatment records, all six maxillary anterior teeth present, no history of craniofacial trauma, absence of congenital anomalies were included. Bearded individuals were excluded. Informed consent was taken from the patients meeting with the inclusion criteria. Lateral cephalograms and lateral profile photographs were taken for each subject.

Radiographic procedure

Digital lateral cephalograms were taken with a Kodak 8000C (Kodak Dental Systems). This radiographic system uses a charge-coupled device sensor chip as an image receptor. The exposure parameters were 70 kV, 10 mA, and 0.6 seconds. Cephalometric radiographs were taken in NHP with teeth in maximum intercuspation and lips at rest. A 30 cm vertical ruler was suspended in front of the patient, in the midsagittal plane, to register the true vertical as well as to allow later measurements at life size (1:1). Standardized lateral cephalograms were obtained for all subjects. The angular parameters included were Sella-Nasion to point A (SNA), Sella-Nasion to point B (SNB), Point A to point B (ANB) and Frankfurt - Mandibular plane angle (FH-MP), whereas, the linear parameters were Total facial height (TFH) i.e. Nasion (N) to Menton (Me), Lower facial height (LFH) i.e. anterior nasal spine (ANS) to Me, Mandibular length (ML) i.e. gonion (Go) to gnathion (Gn) (Figure 1). All lateral cephalograms were analysed using Nemotech software version 6.0 for windows. All the lateral cephalograms were analysed by one operator.

Photographic method

The photographic set up (Figure 2) used was the same as that of Gomes et al. 2013 Standardized right profile photographs were taken in the natural head position (NHP), with maximum intercuspation and lips at rest. Glasses were removed and hair piled high on the head to ensure that the patient's forehead, neck, and ears were clearly visible. Adhesive dots were placed on anatomic landmarks obtained by palpation The Me' point was identified with an adhesive styrofoam bead to allow better visibility in the images. To obtain the natural head posture, a mirror (75 x 30 cm) was fixed on a tripod and the patients were asked to stand at a line drawn 120 cms from the mirror and to keep looking straight ahead into the reflection of their eyes in the mirror. This corresponds to the Broca's natural head posture as defined by Broca in 1862 i.e. 'the position when a man is standing and when his visual axis is horizontal, his head is in natural posture.' The patients were instructed to look straight ahead into the reflection of their eyes in the mirror.A 30 cm vertical scale was adapted in a plumbline which indicated the true vertical. This scale was positioned in the mid sagittal plane to allow later measurements at life size. The same digital camera (cannon, EOS 1300 D) was used for all photographic records. The camera was secured at a tripod stand at a distance of 210 cms from the subject and this distance was fixed for every subject. The 100 mm macro lens was chosen to avoid any facial deformations and to maintain natural proportions. A 30 cm scale was suspended in front of the patient, which indicated the true vertical. The scale was positioned in the mid sagittal plane to allow later measurements at life size (1:1). To convert an image to life size, the magnification factor was calculated by dividing 1 cm by the measurement taken between the centimetre points on the image of the suspended vertical scale in the photograph. This magnification factor was then multiplied by all the linear measurements obtained from the photographs to convert the measurements to life size. Before capturing the lateral photographs, the facial landmarks were identified by palpation and adhesive dots were placed on the subject's face to identify location on the photograph.

1. **Ey:** the lowest point on the right bony orbit found by palpation, corresponding to the cephalometric orbitale point.

2. **Tragion (T):** the point where the inner crease meets the outer edge at the center of the ear, corresponding to the cephalometric porion point.

3. **Point M:** analogous to the gonial angle of the mandible, located by palpation.

4. **Soft-tissue Me (Me):** the most inferior point on the soft-tissue chin.

Before measuring, a piece of acetate tracing paper was attached with adhesive tape to the photo. Eight facial landmarks were identified and transferred to the tracing paper with a pencil. The following reference planes were used for subsequent analysis.

1. Soft-tissue Frankfort horizontal (T to Ey) which corresponds to the Frankfurt horizontal plane (FH).
2. Cranial plane (CP) front point T to soft tissue nasion.
3. Soft-tissue mandibular plane (M to Me) (MP).

The following angular and linear measurements were created from these landmarks and planes (Figure 3)

1. Angular parameters

- TNA (relative maxillary position), analogous to cephalometric SNA.
- TNB (relative mandibular position) analogous to cephalometric SNB.
- ANB' (relationship between maxilla and mandible) corresponding to cephalometric ANB.
- FH-MP (Frankfort horizontal plane to mandibular plane angle).

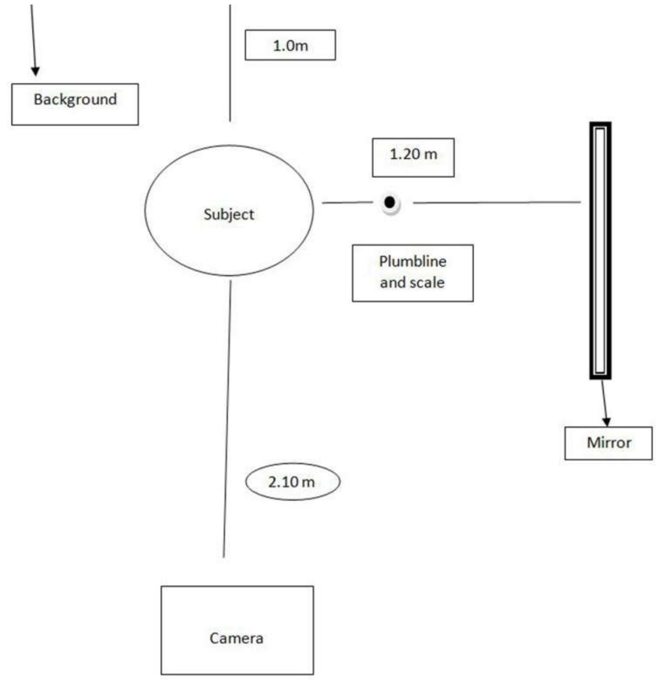

Figure 1. Cephalometric landmarks and parameters taken. Nasion (N), Porion (PO), Sella(S), Orbitale (O), point A, point B, Gonion (Go), Menton (Me)

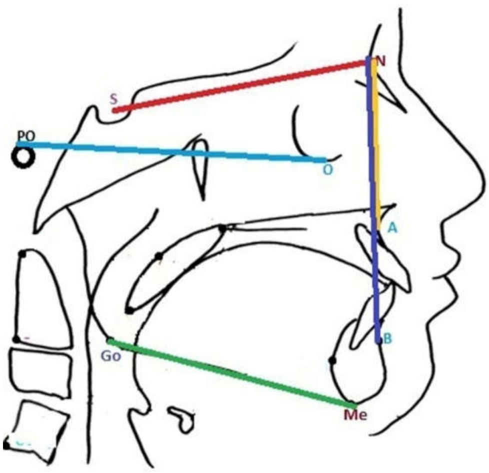

Figure 2. Photographic set up

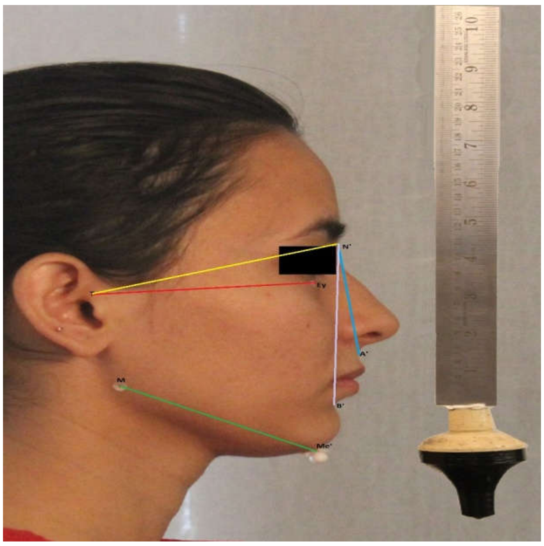

Figure 3. Photographic Landmarks and parameters taken. Soft tissue Nasion (N'), Soft tissue Orbitale (Ey), Tragion (T), Soft tissue Gonion (M), Soft tissue Menton (Me'), Soft tissue point B(B'), Soft tissue point A (A')

2. Linear parameters

- Lower facial height (LFH): linear distance between subnasale and soft tissue menton (Sn and Me').
- Total facial height (TFH): linear distance between soft tissue nasion and soft tissue menton (N' and Me').
- Mandibular length (ML): linear distance between point M and soft tissue menton (Me)

To check the reliability and repeatability of the method these measurements were repeated on the cephalograms and the photographs of 20 randomly selected subjects by taking photographs after 1 week to assess the repeatability. Reproducibility analysis was conducted on a sample of 20 subjects randomly selected. Hence, a second rater repeated the landmark location by palpation and replaced the adhesive dots before taking the picture.

Statistical Analysis

The data was subject to statistical analysis using SPSS software version 23. Descriptive statistics including means, standard deviations, and minimum and maximum values are given for each photographic and cephalometric variable for the entire sample. Sexual dimorphism was evaluated by independent sample t-test. Intraclass correlation coefficients (ICCs) and corresponding 95% confidence intervals (CI) were estimated from repeated photographic measurements to evaluate the repeatability and reproducibility of the method. Cephalometric measurements were compared with analogous photographic measurements to assess Pearson correlation coefficients. The correlations were considered significant at a $p \leq 0.05$.

RESULTS

The photographic technique showed high repeatability and reproducibility regarding diagnostic variables (ICC ≥ 0.90) as illustrated in Table 1. Means, standard deviations, ranges, and gender differences for all cephalometric and photographic measurements were calculated (Table 2 and 3). No significant gender differences were found for cephalometric and photographic measurements, so the data was pooled together as one. Significant correlations ($p \leq 0.01$) were found between cephalometric and photographic measurements for most sagittal and vertical diagnostic variables (Table 4) which ranged from weak to strong. All variables suggested a moderately positive correlation between the corresponding cephalometric and photographic variables. Given the entire sample, the highest coefficients were found between ANB vs A'N'B (0.696) and SNA vs TNA (0.684) and were statistically significant at $p \leq 0.05$ level.

Table 1. Intraclass correlation coefficient value, lower value and upper value of photographic variables at confidence interval of 95%

VARIABLE	ICC	Lower	Upper
TNA	.976	0.930	0.991
TNB	.966	0.905	0.988
ANB'	.989	0.940	0.991
MPA'	.966	0.914	0.986
TFH'	.904	0.761	0.960
LFH'	.950	0.749	0.962
ML'	.822	0.420	0.930

*$p \leq 0.05$ considered significant

Table 2. Mean values, minimum values, maximum values standard deviation and levels of significance of lateral cephalometric variables

Variable	Males				Females				(p values)
	Mean	Std deviat-ion	Min	Max	Mean	Std deviation	Min	Max	
SNA	83.8	4.3	76	93	83.4	4.39	76	93	.803
SNB	80.4	4.5	74	93	80.3	4.6	74	93	.991
ANB	3.5	2.1	-3	10	3.3	2.2	-2	9	.852
MPA	27.2	7.1	13	42	27.1	7.1	13	42	.998
TFH	105	9.2	81	125	103	9.7	81	121	.112
LFH	60.2	6.1	41	70	59.1	6.34	41	70	.218
ML	73	8.02	54	99.1	71.4	9.73	54	99	.244

*p ≤ 0.05 considered significant

Table 3. Mean values, minimum values, maximum values, standard deviation and significance levels (p values) of lateral photographic variables

Variables	males				females				Significance (p)
	mean	STD Deviation	min	max	mean	STD Deviation	min	max	
TN'A'	81	4.4	72	92	81.9	4.7	72	93	.954
TN'B'	74	3.7	67	82	71.9	5	67	92	.122
A'N'B'	6.7	2.4	2	13	5.9	2.7	-1	11	.380
MPA'	28	6.9	12	45	27.4	2.1	10	45	.175
TFH'	107	9.7	90	123	104.1	11.3	80	123	.142
LFH'	63	7.7	40	75	61.3	8.2	40	75	.280
ML'	65	7.3	50	76	63.1	7.6	43	75	.070

*p ≤ 0.05 considered significant

Table 4. cephalometric variables, photographic variables, pearson's correlation values between lateral cephalometric and lateral photographic variables and significance value

Cephalometric variables	Photographic variables	Pearson's correlation	Significance (p)
SNA	TN'A'	0.684	0.000*
SNB	TN'B'	0.628	0.000*
ANB	A'N'B'	0.696	0.000*
MPA	MPA'	0.657	0.001*
LAFH	LAFH'	0.602	0.01*
ML	ML'	0.575	0.017*
TFH	TFH'	0.629	0.007*

*p ≤ 0.05 considered significant

DISCUSSION

The assessment of craniofacial morphology has become one of the key diagnostic criteria during orthodontic diagnosis and treatment planning. Photographs are widely used for documentation in the dental profession, but they are usually analyzed from a qualitative point of view and seldom used for quantitative evaluation, probably because of the lack of carefully standardized techniques, both in taking the pictures and in their evaluation. This prospective cross sectional study was undertaken to assess the correlation of linear and angular measurements taken from the lateral profile photographs with analogous measurements of lateral cephalograms of the same subjects. Considering that all the photographic and cephalometric measurements were performed based on the anatomical landmarks, the repeatability tests hence carried out showed a satisfactory repeatability of this method (Table 1). Previous authors (Ferrario *et al.,* 1993; Fernandez-Riveiro *et al.,* 2002) have reported sexual dimorphism in most parameters of the labial, nasal, and chin areas when evaluating photographs but in this study, no significant gender differences were found (Table 2 and 3) which may be due to a smaller sample size. On comparing the cephalometric and photographic variables for the entire sample, positive and significant correlations (P ≤ .05) were found for all sagittal and vertical diagnostic variables (Table 4). The pearson correlation coefficients ranged from weak to strong meaning that although there was a significant tendency for analogous photographic and cephalometric variables to vary together, this tendency was strong for some measurements and weak for others. Moderately positive but highly significant correlations were found for TNA and SNA and TNB and SNB (p ≤ 0.5). Barnett DP (Barnett, 1975) concluded that the point 'A' and 'B' on the facial skeleton is closely correlated with the position of the corresponding points on the integumental soft tissues. Strong correlations were found between ANB and AN'B'. Bittner and Pancherz (Bittner and Pancherz, 1990) found moderately positive correlations for ANB to A'N'B'. The correlation between skeletal and soft tissue ANB angles was only moderate (r = +0.696), which can possibly be explained by a masking of lip posture and lip morphology (Barnett, 1975). Moderately positive but highly significant correlations were found between FMA/FMA', TFH/TFH' and LFH/LFH'. Our results are in accordance with Zhang *et al.* 2007 One reason for this finding could be that the landmarks used for estimating facial height, N and Me, are not influenced by excessive soft tissues in these areas, and, therefore, the soft tissue is a good estimate of the bony landmark. Our results are consistent with this explanation. Weakly positive but significant correlations were found for ML and ML'. Our results are comparable with those of Zhang *et al.* 2007, who showed moderately positive and significant correlations for Go□Gn and ML. This may be due to difficulty in locating the M point. This problem may have occurred as it is located away from the midline. Photographic analyses are inexpensive, do not expose the patient to potentially harmful radiation, and could provide better evaluation of the harmonic relationships among external craniofacial structures, including contribution of muscles and adipose tissue. According to our results, this method can be used reliably to assess craniofacial morphology during initial orthodontic consultations and epidemiologic studies. Conversely, the photographic technique has some shortcomings, such as the distortion from the distance between the lens and the subject which causes objects near the camera appear larger than those farther from it (Cummins *et al.,* 1995). However, this factor is only critical when one attempts to compare structures located in different planes of space. Most landmarks obtained from lateral photographs in the current study are at the midline, thus making sure that this issue doesn't affect the results. In addition, the problem of magnification does not affect the angular parameters which were used and the magnification error was calculated and reduced in case of all the linear measurements. The morphologic imbalance among different skeletal components can often be masked by soft tissue compensations which might lead to possible errors in measurements. Another source of error concerns is the head posture and therefore it must be kept the same during photographic and radiographic recording protocol. In this study, Broca's natural head posture was used to record both the cephalograms as well as the lateral photographs. Any change from the natural head posture may lead to incorrect conclusions. This study may not be feasible on bearded individuals because of the difficulty in location of points soft tissues Go', Me' and Gn'. The photographic set up also needs to be standardized. Although cephalometrics and photography cannot be used interchangeably since they measure different aspects of craniofacial morphology, photography assumes equal importance as an essential diagnostic aid as there is a paradigm shift towards the soft tissue in orthodontic treatment planning. A possible future application of photography could be in genetic epidemiology and family pedigree studies.

Conclusion

- Positive and significant correlations were found for all linear as well as angular variables. The Pearson correlation coefficients ranged from weak to strong suggesting that there was a significant tendency for analogous photographic and cephalometric variables to vary together.
- Photographs may also be used reliably for epidemiological purposes, screening initial consultations and cases where irradiation is contraindicated and needs to be avoided.
- As cephalometrics and photography cannot be used interchangeably, since they measure different aspects of craniofacial morphology, cephalometrics remains the method of choice for clinical patient care, and photographs might be better for large-scale epidemiologic studies, especially when there is a need for a low-cost, non-invasive method that can be used in diverse clinical and field settings

Conflict of Interest : The authors report no potential conflicts of interest.

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