ISSN: 2639-9210

Annals of Dentistry and Oral Health

Open Access | Research Article

Skeletal, soft tissue and dental cephalometric values in an adult Ethiopian population: A preliminary observational descriptive study

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Received: Nov 22, 2019

Accepted: Dec 23, 2019

Published Online: Dec 27, 2019

Journal: Annals of Dentistry and Oral Health

Publisher: MedDocs Publishers LLC

Online edition: http://meddocsonline.org/

Abstract

Objective: Caucasian cephalometric values are still used for treating Ethiopian patients despite the differences between Ethiopian and Caucasian features. The aims of the study were to determine skeletal, soft tissue and dental cephalometric values for an adult Ethiopian population, and identify any differences between Ethiopian males and females and to evaluate differences between Ethiopian and Caucasian values.

Methods: Participants consisted of 15 males and 15 females with a mean age of 20.8 years with pleasing profiles and normal occlusion. Sixteen angular, seven linear and a percentage measurement were performed. Tracings and analyses were performed using standardized digital films and cephalometric software (OrisCeph Rx1 CE, Italy). Mean values and standard deviations were calculated for each measurement and the p value was set at $p<0.05$.

Results: Maxillary-mandibular planes angle (MMPA, p=0.02), inter-incisal angle (IIA, p=0.03) and lower incisor to mandibular plane angle (IMPA, p=0.02) showed statistically significant differences between the two genders. Females tended to have increased MMPA and IIA but males had more proclined lower incisors with an increased IMPA. On comparison with Caucasians, all values except A point-Nasion-B point angle (ANB), Sella-Gnathion-Nasion angle (Y-Axis-SN), Wits Appraisal and Pogonion to McNamara Nasion Perpendicular showed statistically significant differences ($p<0.05$) indicating that Ethiopian values showed significant differences from Caucasian values.

Conclusion: This sample of adult Ethiopian participants showed significant differences from Caucasians. Such differences should be considered when using cephalometry to assist in orthodontic diagnosis and treatment planning of adult Ethiopian patients.

Cite this article: Ibrahim YS, Singh P. Skeletal, soft tissue and dental cephalometric values in an adult Ethiopian population: a preliminary observational descriptive study. Ann Dent Oral Health. 2019; 2(1): 1010.

Introduction

The introduction of cephalometry into the field of orthodontics was considered a major step forwards for the specialty. Broadbent introduced a new technique to measure the relationships of the jaws in relation to the head by using a standardized cephalometric method [1]. Initially, cephalometry was used primarily to compare normal and abnormal growth patterns but the technique quickly began to be applied to diagnosis, treatment planning and assessment of treatment outcomes.

As a consequence, cephalometric studies of many different ethnic groups are now available, including Downs' study of Caucasians [2], Park et al.'s study of Koreans [3], Chan's study of the Chinese [4], Nanda and Nanda's study of North Indians [5], Garcia's study of Mexican American [6], Drummond's study of Negroes [7], Shalhoub et al.'s study of Saudis [8], Tayyem et al.'s study of Emiratis [9], Al-Jame et al.'s study of Kuwaitis [10], Salama and Abuaffan's study of the Sudanese [11] and Hajighadimi et al.'s study of Iranians [12].

African countries also have cephalometric values for some of their populations. Ajayi studied lateral cephalograms of 100 Nigerian school children and concluded that compared to other races, Nigerians have prognathic maxillae and mandibles and have a tendency for protrusive skeletal patterns [13]. A cross-sectional and multi-national comparative study involving participants from Ghana, Nigeria, and Senegal was conducted by Fadeju et al [14]. The study concluded that few differences existed in the dental and skeletal patterns between the three countries while there was statistically significant difference noted when the study was compared with established Caucasian norms.

All of the above investigators stated that normal measurements from one group should not be considered normal for other ethnic groups. Different ethnic groups have to be treated according to their own individual characteristics. Kavitha and Karthik did a comparison study between Caucasian and non-Caucasian norms and emphasized that ethnic variations significantly affect cephalometric norms [15]. Moyers suggested that a certain norm and analysis will be misused if it is applied to patients of different ages or races [16].

According to Wu et al., craniofacial features like form, size, facial pattern and dental arches are generally accepted to be genetically pre-determined [17]. Richardson reached the conclusion that several factors affect angular and linear measurements [18]. These factors include genetic, geographic, functional, and climate effects.

To the best of the authors' knowledge, no standards are available relating to cephalometric values for the adult Ethiopian population. Ethiopia is the second most populous nation in Africa after Nigeria [19]. Ethiopia is located in East Africa, specifically in the horn of the African continent with a population of more than 100 million and considered to be one of the origins of human beings as a 3.2 million years old well-preserved juvenile partial skeleton of Australopithecus afarensis was discovered in the Dikika region of Ethiopia [20].

Ethiopians have very unique facial skeletal structures that might be significantly different even from other fellow Africans. Passarino et al. studied the genetic components of the Ethiopian population and concluded that the Ethiopian population have Caucasoid, African and Asian genetic pools [21]. Genetic studies have also provided evidence of recent migrations into Ethiopia, of Semitic speaking peoples from Arabia [22]. Levine discussed that migrations from some of the Arabian Peninsula countries to Ethiopia has been seen [23]. These migrations may have influenced the genetic composition of the Ethiopian population.

The aim of this study was to formulate cephalometric values for the adult Ethiopian population and to evaluate whether any significant cephalometric differences exist between Ethiopian adult males and females. The Ethiopians values determined from this study would also be compared with Caucasian values. The results would form an important tool to help in diagnosing and designing a treatment plan for orthodontic and orthognathic patients of the adult Ethiopian population.

Methods

Participants were recruited from undergraduate dental students at Addis Ababa University and patients who visited Gojeb Dental Center, a private practice in Addis Ababa. The total sample size of the study was 30 participants with equal numbers of males and females. This total sample size complied with the Central Limit Theorem, which states that a minimum of 30 participants ($n \geq 30$) is required to assume normality of data, which is a pre-requisite for a parametric test [24].

Ethical approval was obtained from BPP University Ethical Approval Board on 5 May 2018. In addition, local ethical approval was also obtained from Addis Ababa University Dental School on 19 May 2018 [Reference Number DHSTC/260/18].

The inclusion criteria were that participants needed to have a balanced facial profile with competent lips and be without any obvious asymmetry, they needed to be of Ethiopian heritage (by questioning of ancestry), aged 18 to 25 years, have a full permanent dentition (excluding third molars) with class I incisor, canine and molar relations, normal overjet, overbite and transverse occlusion and, well aligned teeth although minor crowding or spacing of less than 3mm was included. Participants also needed to have had no history or previous orthodontic treatment or orthognathic surgery and, in the opinion of the lead author, would not have benefited from orthodontic treatment.

The lead author gave a presentation in June 2018 about the study at the university to dental students and of the 50 that attended, all agreed to participate. All of those potential participants were examined but only 14 fulfilled the inclusion criteria and these were consented to take part in the study. More than 800 potential participants were examined for the study between May 2018 and July 2018 at the private clinic. From those examined, 34 fulfilled the inclusion criteria with 16 consenting to take part in the study.

A digital cephalometric X-ray machine, Kodak Carestream CS 9000 (Carestream Health Inc., 150 Verona Street, Rochester, USA) was used for all participants in the study. OrisCeph Rx1 CE software (Elite Computer Italia Srl, Via A. Grandi, Vimodrone, Italy) was used for electronically tracing and analyzing the cephalometric radiographs. Both the extra-oral imaging system and OrisCeph Rx1 CE software were compliant with directive 93/42/CEE.

Each radiograph was taken by observing the Natural Head Position [25]. Following a standardized positioning protocol, the participants were asked to bite into centric occlusion with lips in the relaxed position. All radiographs were then taken after observing necessary local radiation protection precautionary measures. Calibration was undertaken using an aluminum ruler in the mid-sagittal plane of each digital film.

The software was used to develop a modified custom made cephalometric template that included the selected landmarks and measurements. The lead author undertook all landmark identifications using the software that then undertook the measurements (Table 1). Sixteen angular, seven linear and one percentage (ratio) were calculated. Selected parameters from Steiner, McNamara, Tweed, Ricketts, Downs and Wits Appraisal were included in the cephalometric measurements. All selected measurements are commonly used in most cephalometric studies.

Table 1: Measurements taken in the study.

Measurement	Description
SNA	Sella - Nasion - point A Angle
SNB	Sella - Nasion - point B Angle
ANB	Difference between SNA and SNB Angles
Wits Appraisal	Linear measurement between A and B points projected perpendicular onto the Functional Occlusal Plane
MMPA	Maxillary - Mandibular Planes Angle
FHMA	Frankfort - Mandibular Planes Angle
Y-Axis-SN	Sella - Gnathion - Nasion
Y-Axis-FH	Sella - Gnathion - Frankfort Horizontal
SN-MPA	Sella Nasion - Maxillary Planes Angle
SN-Pog	Sella Nasion - Pogonion Angle
UAFH	Upper Anterior Face Height (Nasion to Anterior Nasal Spine)
LAFH	Lower Anterior Face Height (Anterior Nasal Spine to Menton)
Face Height Ratio	LAFH/TAFH (Total Anterior Face Height)
UI-MPA	Upper Incisor to Maxillary Plane Angle
UI-NA	Upper Incisor to Nasion point A Angle
UI-SN	Upper Incisor to Sella Nasion Angle
LI-MPA (IMPA)	Lower Incisor to Mandibular Plane Angle
LI-NB	Lower Incisor to Nasion point B Angle
IIA	Interincisal Angle
Pog-McNam	Pogonion to McNamara Nasion Perpendicular
A-McNam	Point A to McNamara Nasion Perpendicular
LI-A-Pog	Lower Incisor to A-Pog line
E-Line	Lower lip to Rickett's E line
NLA	Nasolabial Angle

Statistical analysis

Sample characteristics were evaluated by performing a Shapiro-Wilk test for all measurements. The null hypothesis for this test was that the data was normally distributed. The p value was greater than 0.05 for all measurements except for ANB ($p=0.04$), and UI-SN ($p=0.02$). As a result, the data was considered on the whole, to be normally distributed. The data collected was coded and entered into the Statistical Package for Social Sciences software (SPSS) version 24.0 (IBM Corp., Armonk, New York, USA) and statistical analyses were performed.

Despite the tracing and analysis being done electronically with cephalometric software, landmark identification was still carried out manually by the lead author. To avoid possible errors or bias during landmark identification, 10 randomly selected cephalograms were re-analyzed two weeks after the first tracing and analysis. The initial and the repeated cephalometric measurements were compared with a Paired Sample t-Test to determine any systematic error. The chosen level of significance was $p<0.05$. There was good agreement for first and second measurements indicating that there was no significant intra-examiner variability for all measurements except UI-MPA ($p=0.03$) and LAFH/TAFH ratio ($p=0.02$). This may have been due to the inherent difficulty in identifying some of the landmarks.

Mean, median, standard deviations, minimum and maximum values were calculated for each measurement. An Independent Sample t-Test was performed to test for any significance between males and females. A One Sample t-Test was used to compare the results of Ethiopian values with commonly used Caucasian values. The significance level was set at $p<0.05$.

Results

The sample comprised 30 lateral cephalograms of selected Ethiopian adult male and female participants (15 males and 15 females). The mean age of the total sample was 20.8±1.95 years. The mean age of the male sample was 21.8±1.91 years and that of the female sample was 19.8±1.42 years.

Minimum, maximum, mean and standard deviations were calculated for each measurement (Table 2).

Table 2: Descriptive statistics of the total sample (S.D. = standard deviation).

Measurement	N	Minimum	Maximum	Mean	S.D.
AGE	30	18.1 years	24.6 years	20.8 years	2.0
SNA	30	81.9°	86.3°	83.9°	1.1
SNB	30	77.7°	85.3°	81.5°	1.7
ANB	30	0.1°	4.3°	2.3°	1.3
MMPA	30	16.0°	33.7°	25.1°	3.8
FHMA	30	17.4°	30.7°	22.8°	3.1
Y-Axis-SN	30	62.1°	70.8°	66.1°	2.3
Y-Axis-FH	30	54.3°	63.8°	58.5°	2.2
SN-MPA	30	3.2°	9.8°	5.2°	1.6
SN-Pog	30	76.5°	85.3°	81.9°	1.9
UI-NA	30	11.3°	36.0°	27.7°	5.1
UI-SN	30	93.3°	120.4°	111.6°	5.3
IIA	30	104.4°	135.3°	117.6°	6.5
IMPA	30	87.9°	113.7°	100.4°	6.2
UI-MPA	30	89.3°	111.0°	101.7°	4.8
LI-NB	30	21.0°	43.7°	32.3°	4.8
NLA	30	81.7°	110.2°	96.9°	6.5
Wits Appraisal	30	-1.0mm	2.0mm	0.3mm	0.8
UAFH	30	37.1mm	50.6mm	43.2mm	3.3
LAFH	30	52.6mm	69.5mm	59.9mm	4.3
LAFH/TAFH	30	55.1%	61.0%	58.1%	1.6
Pog-McNam	30	0.2mm	6.1mm	2.6mm	1.5
A-McNam	30	0.2mm	3.5mm	1.8mm	0.9
LI-A-Pog	30	0.1mm	8.6mm	4.6mm	1.8
E-line	30	0.1mm	3.6mm	1.7mm	1.1

All measurements except three showed no statistically significant differences between male and female participants (Table 3). MMPA (*p*=0.02), IIA (*p*=0.03) and IMPA (*p*=0.02) showed that there was a significant difference between male and female participants in these measurements with MMPA (males=23.57°; females=26.72°) and IIA (males=115.21°; females=120.16°) being increased in the female sample and males tending to have more proclined lower incisors compared to females (males=102.99°; females=97.76°).

Table 3: Descriptive statistics of the total sample (S.D. = standard deviation).

Independent Samples *t*-Test						
Levene's Test for Equality of Variances						*t*-Test for Equality of Means
Measurement	F	Sig.	*t*-value	*p*-value	Mean Difference	Std. Error Difference
SNA	0.12	0.73	1.90	0.07	0.70°	0.37
SNB	2.00	0.17	0.64	0.53	0.40°	0.63
ANB	0.35	0.56	0.61	0.55	0.230°	0.49
MMPA	0.02	0.89	-2.49	0.02*	-3.15°	1.27
FHMA	0.01	0.91	-0.82	0.42	-0.93°	1.15

Y-Axis–SN	1.07	0.31	-0.70	0.49	-0.60°	0.86
Y-Axis-FH	0.06	0.81	1.02	0.32	0.82°	0.81
SN-MPA	0.13	0.72	1.38	0.18	0.80°	0.58
SN-Pog	0.21	0.65	0.88	0.39	0.64°	0.73
UI-NA	0.00	0.99	0.74	0.47	1.37°	1.86
UI-SN	0.05	0.83	1.07	0.30	2.07°	1.94
IIA	0.11	0.74	-2.24	0.03*	-4.95°	2.21
IMPA	0.21	0.65	2.54	0.02*	5.23°	2.06
UI-MPA	0.21	0.66	-1.11	0.28	-1.93°	1.73
LI-NB	0.77	0.39	1.98	0.06	3.28°	1.66
NLA	1.77	0.19	0.50	0.62	1.20°	2.40
Wits Appraisal	0.01	0.92	0.83	0.42	0.26mm	0.31
UAFH	0.14	0.72	0.46	0.65	0.57mm	1.23
LAFH	4.10	0.05	1.96	0.06	2.95mm	1.51
LAFH/TAFH	0.02	0.90	1.48	0.15	0.86%	0.58
Pog-McNam	0.03	0.87	1.39	0.18	0.72mm	0.52
A-McNam	0.54	0.47	-1.88	0.07	-0.63mm	0.34
LI-A-Pog	4.33	0.05	0.39	0.70	0.25mm	0.65
E-Line	2.33	0.14	1.53	0.14	0.58mm	0.38

A One Sample *t*-Test was performed to compare the mean value results with the established Caucasian values. The comparison of the study sample results with Caucasian values is showed on Table 4. All values except ANB, Y-Axis-SN, Wits Appraisal and Pog-McNam showed statistically significant differences (p<0.05).

Table 4: Ethiopian and Caucasian values (S.D. = standard deviation; *significant p<0.05; +significant *p*<0.01) (Caucasian values taken from Steiner, McNamara, Tweed, Ricketts, Downs and Wits).

One-Sample *t*-Test				
Measurement	**Caucasian Mean (S.D.)**	**Present Study Mean (S.D.)**	**Mean Difference**	***p*-value**
SNA	82° ± 2	83.8°±1.9	0.9°	0.001+
SNB	80° ± 2	81.5°±1.6	1.1°	0.002+
ANB	2° ± 2	2.31°±1.6	0.3°	0.200
MMPA	27° ± 4	25.1°±3.7	-1.9°	0.012*
FHMA	24° ± 4	22.7°±3.1	-1.2°	0.042*
Y-Axis-SN	66° ± 4	66.1°±2.3	0.1°	0.920
Y-Axis-FH	60° ± 4	58.4° ± 2.2	-1.6°	0.001+
SN-MPA	8.5° ± 3	5.2°±1.6	-3.3°	0.001+
SN-Pog	80° ± 2	81.9°±1.9	1.9°	0.001+
UI-NA	22° ± 4	27.6°±5.1	5.7°	0.001+
UI-SN	103° ± 4	111.5°±5.3	8.6°	0.001+
IIA	135° ± 10	117.6°±6.4	-17.3°	0.001+
IMPA	93° ± 4	100.3°±6.1	7.4°	0.001+
UI-MPA	109° ± 4	101.6±4.7	-7.4°	0.001+
LI-NB	25° ± 4	32.3° ± 4.7	7.3°	0.001+

NLA	102° ± 4	96.9° ± 6.5	-5.1°	0.001+
Wits Appraisal	0mm ± 1	0.3mm ± 0.9	0.2mm	0.120
UAFH	53mm ± 4	43.2mm ± 3.3	-9.8mm	0.001+
LAFH	75mm ± 7	59.9mm ± 4.3	-15.1mm	0.001+
LAFH/TAFH	56% ± 7	58.1% ± 1.6	2.1%	0.001+
Pog-McNam	2mm ± 2	2.6mm ± 1.5	0.4mm	0.140
A-McNam	0.5mm ± 1	1.8mm ± 0.9	1.3mm	0.001+
LI-A-Pog	1.0mm ± 2	4.6mm ± 1.8	3.6mm	0.001+
E-Line	-2mm ± 2	1.7mm ± 1.1	0.7mm	0.002+

Discussion

The present study attempted to establish skeletal, soft tissues and dental values for this adult Ethiopian sample. The results were compared with the commonly used Caucasian values. The study comprised equal numbers of male and female participants. Potential participants were recruited from patients visiting Gojeb Dental Clinic and Addis Ababa University dental students.

Among those who fulfilled the inclusion criteria from private practice, significant numbers declined to participate in the study. Some agreed to participate but did not attend for the taking of the radiograph. An explanation for this cannot be offered although it can be speculated that these potential participants did not fully appreciate the importance of the study, despite this being explained to them. On the other hand, all university students examined agreed to be part of the study and all those who met the inclusion criteria indeed finally participated by having a radiograph taken. This may be because the university students better appreciated the purpose of the study.

Most of the results showed no significant difference between male and female samples.Only three parameters showed statistically significant differences between male and female subjects. These parameters were MMPA, IIA and IMPA (p value<0.05).

Most of the mean results showed significant difference from Caucasian values implying that the population has distinct features different from Caucasians.

On evaluation of the sagittal relationship in the present study, it was clearly seen that angles SNA and SNB values showed statistically significant differences compared to Caucasian values indicating more prognathic maxilla and mandible positions in the study sample. The ANB value did not show significant differences from the Caucasian values. On linear parameters, Wit’s Appraisal was within range of Caucasian values. Other linear measurements were A-McNam and Pog-McNam. The result of the former showed increased values compared to the Caucasian norms confirming the SNA angular value result. Pog-McNam also coincided with the SNB result showing an increased value.

For vertical dimensions, linear measurements as well as one percentage was analyzed. The angular measurements were MMPA, FMPA, Y-Axis-SN, and Y-Axis-FH. All these measurements except Y-Axis-SN (p=0.92) showed smaller values than Caucasian values with statistically significant differences (p<0.05). The two linear measurements UAFH and LAFH values also showed statistically significant smaller values than the Caucasian values. High angular measurements indicate a vertical or downward pattern of growth while lower angles show horizontal or forward pattern of growth. The values indicated a more horizontal growth pattern of the mandible in the Ethiopian sample compared to Caucasians.

The position and inclination of upper incisors was evaluated by measuring UI-NA, UI-SN and UI-MPA. The first two parameters showed increased values, that were statistically significant, indicating that the study showed more proclined upper incisors than Caucasian values. UI-MPA showed a decreased value that was also statistically significant, probably effected by the fact that the present study had decreased vertical dimensions with a more horizontal growth pattern.

The position and inclination of the lower incisors were evaluated by measuring IMPA, LI-NB and LI-A-Pog. All values showed significantly increased measurements indicating a more proclined lower incisor position in the study compared to Caucasians.

The relationship of upper and lower incisors to each other was evaluated by calculating the measurement of IIA. The results of the present study showed a statistically smaller value compared to Caucasian norms. This signifies more proclined upper and lower incisors resulting in a decreased IIA.

One angular and another linear measurement were calculated to assess the soft tissue characteristics of the study sample. The NLA value (96.9°±6.5.) showed a decreased value compared to Caucasians (102°±4). The NLA result compared to Caucasians showed a more acute angle. The E-line value of the study (1.7mm±1.1) was slightly higher than that of Caucasians (-2mm±2), indicating a more convex profile.

The small sample size should be taken into consideration when interpreting the results of this study. Despite a sample size of 30 participants, when males and females were compared, the sample was halved at 15 in each group. It has already been reported that the migration may have influenced the genetic composition of the Ethiopian population [21-23], so applying values to the general adult population of Ethiopia should be done with caution.

In addition, age limitation where the study group was limited to 18-25 years would invalidate the application of the study results to growing patients. Selection and measurement bias may have been introduced as selection of the sample was limited to two sites and a single operator undertook all measurements. Although statistically significant differences have been seen, it has to be questioned just how clinically significant the differences are.

Despite cephalometry becoming a standard diagnostic tool in orthodontic and orthognathic treatments, the inherent limitations of cephalometry should be kept in mind given that the human head is a three dimensional entity which is converted into two dimensions by the cephalogram that inevitably results in loss of some information [26].

McNamara stated that cephalometric analyses have been used extensively in orthodontics because lateral cephalometric radiographs are obtained easily and tracings and measurements can also be performed relatively quickly [27]. A treatment plan based on a detailed cephalometric analysis evaluation to ensure an ideal outcome is no longer considered to apply. Our face is a three-dimensional entity, which is condensed into a two-dimensional one by the cephalogram. This is generally accepted for the sake of simplicity but one should bear all the limitations in mind [28].

The importance of cephalometry has been, and continues to be questioned in the literature. Björk and Solow discussed that errors can be from projections, identification of landmarks and performing the measurements [29]. Baumrind and Frantz studied the reliabilities of measurements with respect to identification of landmarks and angular and linear measurements [30]. They found errors in measurements, which they divided into errors of projection, errors in landmark identification and errors occurring during drawing lines and measuring distances and angles. Despite this, cephalometry remains an important tool for assisting in diagnosis and planning as long as it is used carefully and with the limitations in mind.

Conclusion

The study population showed few statistically significant differences between adult Ethiopian males and females. The study revealed statistically significant differences between adult Ethiopian and Caucasian samples for the majority of measurements clearly showing that the adult Ethiopian population has distinct features. From the overall findings of the study, and with the aforementioned limitations in mind, it can be concluded that established norms would be needed for orthodontic treatment planning in the Ethiopian population. This study represents a starting point for future studies based on the Ethiopian population.

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