Ann Med Res 2020;27(4):1246-51

Annals of Medical Research
DOI: 10.5455/annalsmedres.2019.11.725

Original Article

Comparison of cephalometric measurements of living subjects and ancient skulls in Anatolia

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Abstract

Aim: This study aims to provide insights into the evolutionary adaptation of human, via comparing the craniofacial characteristics of living subjects and ancient skulls from Anatolia.

Material and Methods: Cone-beam computed tomography (CBCT) generated 2D cephalometric projections of 32 ancient skulls and well matched lateral cephalometric images of 32 patients were evaluated. Sixteen widely used cephalometric measurements were performed. Intra-class correlation coefficients were used to examine intra-observer reliability. Mann–Whitney tests and chi-square tests were used to compare cephalometric measurements of the groups.

Results: : The linear measurements of living subjects were smaller than the linear measurements of ancient skulls (p<0.05). Significant differences were found between the groups in the cranial base lengths, maxillary and mandibular dimensions (p<0.05). The maxilla and mandible were found more prognathic in ancient men and women (p<0.001).

Conclusion: Environmental factors and genetic changes lead to a reduction in the sagittal and vertical dimensions of the human craniofacial complex. Dental practitioners should consider these evolutionary changes during the treatment planning process.

Keywords: Anatolia; ancient populations; craniofacial measurements; cephalograms

INTRODUCTION

Craniofacial traits provide valuable insights into the evolutionary adaptation of human being (1). They give important clues about the ethnic and biological proximity of prehistoric and contemporary populations. Size and shape of craniofacial complex, or facial pattern exhibit variations among different genera, species, races, and sub-races (1-4). Unlike serological characters, craniofacial traits can be studied in both living and prehistoric samples. It also has a high heritability; and more demonstrative than other skeletal features (1).

Anatolian land has hosted numerous civilizations because of its geopolitical position between Asia and Europe, favorable climate, possibilities of agriculture and animal husbandry, and trade routes. These properties have made Anatolia a valuable region for biodiversity. The human population lived in Anatolia are known as Hittites, Phrygians, Ions, Lydians, Urartians, Sumerians, Akkadians, Babylonians, Assyrians, Persians, Macedonians (Hellenistic period), Romans and Turks (5). Anatolia was subjected to intense gene flow since it is an important passage for various human populations (6). So comparative studies covering a large time interval in this region will be beneficial in demonstrating the effects of intensive gene flow on craniofacial morphology.

To our knowledge, this is the first study evaluated the craniofacial characters of an ancient Anatolian population. It might contribute a better understanding of the morphological characteristics of this ancient population and evolutionary trend over a thousand years.

Received: 13.11.2019 **Accepted:** 04.02.2020 **Available online:** 26.04.2020
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MATERIAL and METHODS

The study protocol was carried out according to the principles of the Helsinki Declaration, including all amendments and revisions. Collected data were only accessible to the researchers. Patients or their legal delegates gave their informed consent prior to radiography, and the study was reviewed and approved by the institutional ethical board of the university (study number: 2017/35).

It was found to work with a total of 64 samples, 32 samples in each group with 80% power, 5% type 1 error and an effect size of 0.63 (7) by using G * power 3.1.2 program.

For this purpose, CBCT-generated 2D cephalometric projections of 32 ancient dry skulls (18 male, 14 female) were used that were unearthed from Anatolia, Turkey, and were dated approximately to the period of 800–1,000 C.E (Common Era). Sex and age are estimated by morphological analysis (8-10). The minimum estimated age was 21 years, and the maximum estimated age was 61 years. Inclusion criteria for the skulls were defined as the presence of an intact skull, the absence of evidence of bone pathology and presence of dentition to preserve and stabilize the intercuspal position of the jaws.

In addition to these ancient skulls, 32 age- and gender-matched lateral cephalometric radiographs of contemporary individuals (18 males and 14 females) from Anatolia were included. The samples were selected similar to the ancient skulls regard to the sagittal skeletal relationship (11). The contemporary group was formed similar to skeletal classification (Skeletal class 1/2/3) of the ancient group by considering the ANB angles. Lateral cephalometric radiographs were taken previously for orthodontic purposes according to a strict protocol. The mean age of male subjects was 42.8±11.35, and the mean age of females was 38.2±9.94. The inclusion criteria for patients were as follows: no evidence of current orthodontic treatment, no missing permanent incisors or first molars, no gross skeletal asymmetries, and no bone diseases.

Table 1. Definitions of the cephalometric landmarks used in the present study

Cephalometric landmarks	Abbreviations	Definitions
Nasion	N	Most anterior point of the frontonasal suture in sagittal view
Sella	S	Center of the pituitary fossa
Basion	Ba	Most anterior point of the foramen magnum
Articulare	Ar	The intersection between the posterior contour of the mandible and inferior border of cranial base
A point	A	Point of maximum concavity in the midline of the alveolar process of the maxilla in the sagittal view.
B point	B	Point of maximum concavity in the midline of the alveolar process of the mandible in sagittal view.
Anterior Nasal Spine	ANS	The most anterior midpoint of the anterior nasal spine of the maxilla
Posterior Nasal Spine	PNS	The most posterior midpoint of the posterior nasal spine of the palatine bone
Menton	Me	Most inferior point of the mandibular symphysis in the sagittal view.
Gnathion	Gn	The most anteroinferior point on the mental symphysis
Pogonion	Pog	The most anterior midsagittal point along the convexity of the chin of the mandibular body in the sagittal view.
Condylion	Co	Most superior point of the mandibular condyle (viewed sagittally and anteroposteriorly)
Porion	Po	Most superior point of the external acoustic meatus
Orbitale	Or	Most inferior point of the infraorbital rim
Gonion	Go	The deepest point of the curvature of the angle of the mandible between the inferior border of corpus and posterior border of the ramus of mandible in sagittal view.

CBCT Imaging

CBCT images were taken with Planmeca Promax 3D Max CBCT (Planmeca Oy, Helsinki, Finland) according to a strictly standardized scanning protocol. The exposure parameter settings included: 96kVp, 12mA, 23x16 cm FOV. The exposure time was 18 seconds, and a 360° turn was selected. CBCT images were exported in DICOM file format with a 512 x 512 matrix and imported to Romexis® software (Romexis 3.2, Planmeca, Helsinki, Finland) to generate virtual cephalometrics (12).

Cephalometric analysis

Fifteen cephalometric landmarks (Table 1) were selected. Then 16 widely used measurements selected from Steiner, Bjork, Downs, and Ricketts analysis (8 linear and 8 angular) were performed by using Romexis® software (Romexis 3.2, Planmeca, Helsinki, Finland). To determine intra-observer variability, the observer performed the analysis twice with an interval of 2 weeks.

Statistical Analysis

The SPSS 21 software program (IBM Corp, Armonk NY, 10504, USA) was used to perform the statistical analysis. Intra-observer reliability was assessed by calculating intra-class correlation coefficients (ICC) and their 95% confidence intervals. ICC results were considered low in the range of 0.26–0.49, moderate in the range of 0.50–0.69, high in the range of 0.70–0.89, and very high in the range of 0.90–1.00. Reliability results were moderate to very high with ICC values ranging from 0.69 to 0.98.

Mann–Whitney U and chi-square tests were used to compare the groups. A p-value less than 0.05 was considered statistically significant.

RESULTS

In general, there were significant differences between the linear measurements of the groups in both cranial and facial structures ($p<0.001$) (Table 2-3).

Anterior and posterior cranial bases were significantly shorter in the modern group ($p<0.001$), whereas cranial base angle and saddle angle were similar in both groups ($p<0.05$).

Table 2. Comparison of the groups according to the cranial base measurements

		Ancient Median (min-max)	Modern Median (min-max)	p
Cranial base angle	(N-S-Ba) (°)			
	Males	136.2 (88.8-199.3)	130.5 (113-150)	>0.05
	Females	134.2 (77.5-140.5)	129.5 (113-138)	>0.05
Saddle angle	(N-S-Ar) (°)			
	Males	115.7 (104.7-134.6)	122 (108-133)	>0.05
	Females	125.9 (100.9-137.3)	121 (108-133)	>0.05
Anterior cranial base length	(N-S) (mm)			
	Males	96.1 (68.8-136.5)	68 (55-88)	**<0.001**
	Females	91.3 (77.9-103.6)	66.5 (59-75)	**<0.001**
Posterior cranial base length	(S-Ar) (mm)			
	Males	51.6 (39.9-86.4)	35 (26-42)	**<0.001**
	Females	47.1 (38.4-82.1)	36.5 (25-52)	**<0.001**

The maxilla and mandible were found more prognathic in ancient men and women ($p<0.001$). Facial convexity values of the ancient group were slightly higher than the modern, however, it was not significant enough to make a statistical difference ($p>0.05$). When the dimensional measurements of maxilla and mandible are evaluated (effective maxillary and mandibular lengths, ramus height, mandibular body length), it was seen that the modern group has significantly smaller jaws ($p<0.001$).

Regarding vertical dimensions, it was found that the modern group has significantly shorter anterior lower facial height (ANS-Me) than the ancient group. The angle between the anterior cranial base and the lower edge of the mandible (S-N/Go-Me), which provides information about the vertical dimension of the face, was smaller in the modern group ($p<0.001$).

The measurements affecting the facial proportions like the ratio of posterior facial height to anterior facial height, and the palatal plane angles were similar for both groups ($p>0.05$).

Table 3. Comparison of the groups according to the facial skeleton measurements

		Ancient Median (min;max)	Modern Median (min;max)	p
Sagittal position of the maxilla (Steiner)	SNA (°)			
	Males	87.6 (73.1;91.1)	82 (70;89)	**<0.05**
	Females	83.9 (79.4;89.9)	82 (74;86)	**<0.05**
Sagittal position of the mandible (Steiner)	SNB (°)			
	Males	84.4 (64.6;94.5)	78 (68;87)	**<0.05**
	Females	83.5 (74.5;94.6)	79 (69;91)	**<0.05**
Sagittal position of the jaws relative to each other (Steiner)	ANB (°)			
	Males	3.7 (-16.5;8.5)	4 (-3;7)	>0.05
	Females	5 (-4;12.1)	3 (-1;8)	>0.05
Facial convexity (Rickets)	(N-Pog)-A (mm)			
	Males	3.1 (-25.6;11.4)	2 (-12;6)	>0.05
	Females	3.1 (-14;14.2)	1 (-5;9)	>0.05
Maxillary length (McNamara)	Co-A (mm)			
	Males	119.6(104.1;137)	81 (76;90)	**<0.001**
	Females	112.7(106.3;128.1)	80 (71;90)	**<0.001**
Mandibular length (McNamara)	Co-Gn (mm)			
	Males	156.5 (140.9;195.3)	112.5 (102;136)	**<0.001**
	Females	144.8 (134.6;165.4)	110.5 (103;126)	**<0.001**
Ramus height (Bjork)	Co-Go (mm)			
	Males	72.2 (53.1;83.5)	47.5 (38;62)	**<0.001**
	Females	67.6 (52.1;76.7)	47.5 (40;55)	**<0.001**
Mandibular body length (Bjork)	Go-Me (mm)			
	Males	100.4 (94.5;109.4)	65 (60;79)	**<0.001**
	Females	97.2 (82.8;111.3)	65 (58;72)	**<0.001**
Lower anterior face height (McNamara)	ANS-Me (mm)			
	Males	87.5 (58.6;107.1)	71 (50;87)	**<0.001**
	Females	83 (50.4;108.1)	70.5 (63;98)	**<0.05**
The angle between the anterior cranial base and the lower edge of the mandible (Rickets)	S-N/Go-Me (°)			
	Males	105.3 (87.9;138.8)	98.5 (78;105)	**<0.001**
	Females	106.9 (101.3;135)	99.5 (93;121)	**<0.001**
Palatal plane/FH angle (Rickets)	Po-Or/ANS-PNS (°)			
	Males	2.3 (-9;14.4)	6 (-6;16)	>0.05
	Females	-2.1 (-8.1;7.8)	1 (-7;13)	>0.05
The proportion of posterior face height to anterior face height	S-Go/N-Me (°)			
	Males	70.1 (54.9;99.9)	67.5 (54;78)	>0.05
	Females	70.7 (60.3;88.4)	68 (55;79)	>0.05

DISCUSSION

Cranial base

Many comparative craniometric studies (1, 4, 7, 13) have shown that cranial base angle is an indicator of genetic homogeneity, and it has remained unchanged for centuries within populations. In the current study it was found that although the demographic structure of the region changed considerably throughout a thousand years, the cranial base angle remained intact. So the findings of the present study strengthen the argument that the cranial base angle can be considered as a reliable norm within populations.

Cranial base length is another important parameter that affects other facial structures. Studies have reported that short anterior cranial bases are implicated as a factor in maxillary retrusion (14-16). It has been reported in a mice study that bone formation in the sphenoethmoidal synchondrosis on the anterior cranial base has significant effects on maxillary growth and maxillary morphology (17). In parallel with these reports, decreases in the anterior cranial base length observed in the modern series were accompanied by a maxillary reduction (Effective maxillary length and SNA were considerably lower in the modern group). However, the results of this study are not sufficient to explain this argument entirely because the results of this study do not provide any clarity about whether the maxillary length decreases occur as a result of a reduction in the anterior cranial base, or if the structures in the craniofacial complex have a tendency to decrease in general.

Facial Skeleton

The findings of the present study showed that modern people have more retrognathic and smaller jaws, despite having similar facial convexity angles with the ancient people. These findings are consistent with many comparative studies (4, 10, 11). The possible reasons for these results may be attributable to genetic factors (hybridization, natural selection, and genetic drift) or environmental factors or a combination of both. Environmental effects include 1) posterior displacement of the maxilla in order to reduce the upper airway due to increased air pollution and allergens in recent centuries, 2) volumetric reduction of the jaws due to the reduced masticatory function (5). Also the decreases in linear measurements can occur as a result of different environmental stress levels leading to developmental retardations (18). However, it is still unclear to what extent the environmental factor is responsible for these changes because it is not yet possible to determine how much of the changes are caused by genetic differences.

It was emphasized that, in ancient and modern skull series, skeletal structures that constitute the profile were similar regarding position and shape but different in size (1, 7). The authors speculated that the differences in these linear measurements could be attributed to age differences between the groups. In the present study, on the other hand, we compared two groups that were well-matched regarding age and sex. So the results of the present study showed that there is a maxillary and mandibular reduction in modern humans in sagittal and vertical dimensions and it cannot be attributed to age variation. This notion is consistent with the literature (2, 19) indicating that the facial skeleton has diminished in size over centuries. And this secular trend, including the jaws, may be responsible for the increase in the incidence of crowding, impacted or congenitally missing teeth in modern populations (20-22).

When the results are evaluated in terms of dental practice, the secular shrinkage of the jaws brings to mind the concept of shortened arches. It usually caused by orthodontic extraction treatments or some other prosthodontic reasons. And this concept seems to be an applicable treatment modality due to the consistency of the results with this evolutionary trend of the jaws.

CONCLUSION

Environmental factors and genetic changes lead to a reduction in the sagittal and vertical dimensions of the human craniofacial complex. The shrinkage is more prominent in linear measurements. Dental practitioners should consider these evolutionary changes during the treatment process.

Competing interests: The authors declare that they have no competing interest.
Financial Disclosure: There are no financial supports.
Ethical approval: The study was approved by the institutional ethical board of the university (IRB approval number: 111-2017/35).

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REFERENCES

1. Argyropoulos E, Sassouni V, Xeniotou A. A comparative cephalometric investigation of the Greek craniofacial pattern through 4,000 years. Angle Orthod 1989;59:195-204.
2. Rock W, Sabieha A, Evans R. A cephalometric comparison of skulls from the fourteenth, sixteenth and twentieth centuries. Br Dent J 2006;200:33.
3. Papagrigorakis MJ, Kousoulis AA, Synodinos PN. Craniofacial morphology in ancient and modern Greeks through 4,000 years. Anthropol Anz 2014;71:237-57.
4. Cappabianca S, Perillo L, Esposito V, et al. A computed tomography-based comparative cephalometric analysis of the Italian craniofacial pattern through 2,700 years. Radiol Med 2013;118:276-90.
5. Kuhn SL. Paleolithic Archeology in Turkey. Evol Anthropol 2002;11:198-210.
6. Kilinc GM, Koptekin D, Atakuman C, et al. Archaeogenomic analysis of the first steps of Neolithization in Anatolia and the Aegean. Proc Biol Sci 2017;284.

7. Seddon RP. A cephalometric study of the Romano-British. Eur J Orthod 1984;6:303-12.
8. Brothwell DR. Digging up bones: the excavation, treatment, and study of human skeletal remains. 3rd edition. Cornell University Press 1981.
9. Ubelaker DH. Manuals on Archeology. In: Human Skeletal Remains: Excavation, Analysis, Interpretation. 3rd edition. Washington: Taraxacum 1999.
10. Luther F. A cephalometric comparison of medieval skulls with a modern population. Eur J Orthod 1993;15:315-25.
11. Defraia E, Camporesi M, Marinelli A, et al.Morphometric investigation in the skulls of young adults. A comparative study between 19th century and modern Italian samples. Angle Orthod 2008;78:641-6.
12. Debelmas A, Ketoff S, Lanciaux S, et al. Reproducibility assessment of Delaire cephalometric analysis using reconstructions from computed tomography. J Stomatol Oral Maxillofac Surg 2020;121:35-9.
13. Esclassan R, Noirrit E, Guyonnet JJ, et al.Comparative study between medieval (12th -14th c.) and modern skulls samples of five cranio-facial measures. Rev Stomatol Chir Maxillofac 2006;107:17-22.
14. Hopkin GB, Houston WJ, James GA. The cranial base as an aetiological factor in malocclusion. Angle Orthod 1968;38:250-5.
15. Moss ML, Greenberg SN. Postnatal growth of the human skull base. The Angle Orthodontist 1955;25:77-84.
16. Gong A, Li J, Wang Z, et al. Cranial base characteristics in anteroposterior malocclusions: A meta-analysis. Angle Orthod 2016;86:668-80.
17. Lozanoff S, Jureczek S, Feng T, eet al. Anterior cranial base morphology in mice with midfacial retrusion. Cleft Palate Craniofac J 1994;31:417-28.
18. Brin I, Ben-Bassat Y, Smith P. Craniofacial morphology of Jews from the Hellenistic period. Int J Anthropol 1992;7:19-25.
19. Moore WJ, Lavelle CL, Spence TF. Changes in the size and shape of the human mandible in Britain. Br Dent J 1968;125:163-9.
20. Weiland FJ, Jonke E, Bantleon HP. Secular trends in malocclusion in Austrian men. Eur J Orthod 1997;19:355-9.
21. Altug-Atac AT, Erdem D. Prevalence and distribution of dental anomalies in orthodontic patients. Am J Orthod Dentofacial Orthop 2007;131:510-4.
22. Cirpan S, Kumbuloglu O, Yonguc GN, et al. Anatomical and Radiological Investigation of Dry Bone Adult Mandibles Having Impacted Third Molar Teeth. J Craniofac Surg 2018;29:1060-3.