Three-dimensional geometric analysis of facial symmetry in skeletal class I individuals

İskelet sınıf I bireylerde yüz simetrisinin üç boyutlu geometrik analizi

Abstract

Aim: Our aim in this study is to determine anatomical points to detect asymmetry on both sides of the face, to make morphometric measurements according to age/sex, and to compare facial asymmetry index values according to sex.

Methods: Three-dimensional (3D) Computed Tomography (CT) images of 90 individuals of both sexes (45 female, 45 male) were included in our study. Morphometric measurements of the face were made using the 3D Slicer software package on these images. To evaluate facial asymmetry in more detail, measurements were made using 3D-CT, and asymmetry index values were calculated.

Results: When we analyzed according to sex, female right Condylion-Gonion-Menton angle (CoGoMe_R˄) values were statistically higher than males (p=0.049). There was no statistical difference between the asymmetry index values of males and females (p>0.05). According to the Pearson correlation test, a statistically weak positive correlation was found between age with CoGoMe_R˄, left Condylion-Gonion-Menton angle (CoGoMe_L˄) (in both r=0.228, p=0.031), and Condylion-Menton (CoMe) asymmetry (r=0.237, p=0.024). According to the Pearson correlation test, a statistically weak negative correlation was found between age and Condylion-Subspinale (CoSs) asymmetry (r=-0.209, p=0.048).

Conclusions: It is observed that the measurements around the mandible show more changes with age. In sex comparisons, although most of the facial morphometric measurements of males were significantly larger than those of females, no significant difference was found in the asymmetry index values.

Keywords: Facial asymmetry; sex; three-dimensional imaging; tomography

Öz

Amaç: Bu çalışmadaki amacımız yüzün her iki tarafındaki asimetriyi tespit edebilmek için anatomik noktaları belirlemek, yaşa/cinsiyete göre morfometrik ölçümleri yapmak ve yüz asimetri indeks değerlerini cinsiyete göre karşılaştırmaktır.

Yöntemler: Çalışmamıza her iki cinsiyete ait 90 bireyin (45 kadın, 45 erkek) üç boyutlu (3D) Bilgisayarlı Tomografi (BT) görüntüleri dahil edilmiştir. Bu görüntüler üzerinden 3D Slicer yazılım paketi kullanarak yüzün morfometrik ölçümleri yapılmıştır. Yüz asimetrisinin daha ayrıntılı değerlendirilebilmesi için 3D-CT kullanılarak ölçümler yapıldı ve asimetri indeks değerleri hesaplandı.

Bulgular: Cinsiyete göre incelediğimizde, kadınların sağ Condylion-Gonion-Menton açı değerleri erkeklerden istatistiksel olarak yüksekti (p=0.049). Erkek ve kadınların asimetri indeks değerleri arasında istatistiksel olarak fark bulunmadı (p>0.05). Yaş ile sağ Condylion-Gonion-Menton açısı, sol Condylion-Gonion-Menton açısı (her ikisinde r=0.228, p=0.031) ve Condylion-Menton asimetrisi (r=0.237, p=0.024) arası Pearson korelasyon testine göre istatistiksel olarak anlamlı zayıf pozitif korelasyon bulundu. Yaş ile Condylion-Subspinale asimetrisi arası Pearson korelasyon testine göre istatistiksel olarak anlamlı zayıf negatif korelasyon bulundu (r=-0.209, p=0.048).

Sonuçlar: Mandibula etrafındaki ölçümlerin yaşla birlikte daha çok değişiklik gösterdiği gözlenmektedir. Cinsiyet karşılaştırmalarında ise, erkeklerin yüz bölgesindeki morfometrik ölçümlerinin birçoğu kadınlara göre anlamlı olarak büyük olmasının yanında asimetri indeks değerlerinde anlamlı fark bulunmadı.

Anahtar Sözcükler: Cinsiyet; tomografi; üç boyutlu görüntüleme; yüz asimetrisi

Nihal Gurlek Celik[1], Burcu Akman[2], Rabia Koca[3]

[1] Department of Anatomy, Faculty of Medicine, Amasya University

[2] Department of Radiology, Faculty of Medicine, Amasya University

[3] Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Afyonkarahisar Health Sciences University

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Corresponding author/*Yazışma yazarı*

Nihal Gurlek Celik
Amasya Üniversitesi, Tıp Fakültesi, Anatomi Anabilim Dalı, Amasya, Türkiye.
E-mail: nihal.g.celik@gmail.com

ORCID
Nihal Gurlek Celik: 0000-0002-1204-2668
Burcu Akman: 0000-0002-1067-9008
Rabia Koca: 0000-0002-9052-3002

INTRODUCTION

Symmetry is equality around a center and axis or on both sides of the body (1). Asymmetry is the deterioration and incompatibility of the ratio between the tissues. Facial asymmetry is the deterioration of proportion and harmony on both sides of the face (2). There is no completely symmetrical human face due to different reasons such as genetic factors, environmental conditions, and various diseases (3,4). Mild facial asymmetries are considered normal and do not pose a problem in terms of both aesthetics and function (5). Significant asymmetries may occur due to differences in bone structure and surrounding soft tissues. However, it can cause a decrease in facial attractiveness, deterioration of various functions, and psychosocial problems (6).

As it moves away from the cranium, asymmetry increases in the lower parts of the face (7). Due to the different growth rates of the mandible, the deviation in the lower parts of the face is higher in terms of amount and frequency than the deviation in the upper parts of the face (8). Mandibular condyle height inequality is the most important cause of lower facial asymmetries (9). For this reason, it causes the chin tip to be shaped towards the short condyle side (10).

One of the most important causes of facial asymmetry is the nose in the middle of the face (11). The nose is important in determining facial symmetry, and the curved nose is effective in facial development. In addition, researchers have argued that nasal curvature and facial asymmetry can be seen together (12).

The ideal proportions of the face are a subject that artists and health professionals often research. In recent years, it has begun to attract the attention and research of many professional groups. In particular, orthodontists try to achieve proper facial symmetry and provide a fully balanced occlusion (13). The angle measured between the Subspinale (A), Nasion (N), and Supramental (B) points is called the ANB angle. This angle gives information about the anteroposterior position of the maxilla and mandible bones (14,15). The place of ANB measurement is important in a person's skeletal classification. In the studies conducted, ANB angle measurement between 0˚ and 4˚ is stated as Class I (normal jaw development) (16,17). While malocclusion can be treated if it is caused by face type, congenital face proportions cannot be changed (18).

In recent years, three-dimensional (3D) imaging methods have been used to analyze different body structures (19,20). Because 3D images provide accurate and detailed information, especially in evaluating asymmetric facial structures, allowing the structures to be observed from every angle. The use of Computed Tomography (CT) has become one of the methods that provide the most comprehensive and accurate results in evaluating craniofacial structures (21).

This study, it was aimed to determine the presence of asymmetry on both sides of the face using 3D-CT images, to make morphometric measurements according to sex/age, and to compare facial asymmetry index values according to sex. Data obtained from the article is thought will be helpful for similar studies to be carried out in fields such as plastic surgery, dentistry, and maxillofacial surgery.

MATERIALS AND METHODS

Participants

CT images of 90 healthy individuals (45 female, 45 male) aged 18-57 years were included in the study. CT data are between June 2022 and August 2022. Sample size calculation was calculated with the G*Power program (version 3.1.9.6, Franz Faul, Universität Kiel, Germany) as an effect size of 0.6, alpha level of 0.05, and a study power of 0.80, with a minimum number of samples of 90 (45 in each group). In addition, individuals who have not undergone brain and maxillofacial surgery, have no congenital or traumatic craniofacial deformity, have no pathology in the facial bones, and have an ANB angle between 0-4º (Class I, normal jaw development) were included in the study (Figure 1).

The approval of the Amasya University Non-Interventional Clinical Research Ethics Committee (Date: 02.03.2023, Approval Decision No: 2023/21) was obtained.

CT-scan Acquisition

CT scans of all individuals were performed on 128-slice GE Healthcare Revolution EVO CT (GE Medical Systems; Milwaukee, WI) and multi-detector CT scanners. Tube voltage, 120 kVp; tube current, 100–450 mA; scanning direction, craniocaudal; rebuild kernel, standard; section thickness, 0.625 mm; and section overlap, 0.625 mm. After shooting, axial and sagittal multi-plane reformat (MPR) images were obtained with a section thickness of 0.625 mm.

3D Image Processing

This study was a retrospective analysis of head computed tomography (CT) scans of individuals admitted to the radiology department. Images of all individuals were recorded in DICOM (Digital Imaging and Communications in Medicine) format. These recorded DICOM data were transferred to a personal computer, and free, open-source software, 3D Slicer (https://www.slicer.org/, version 4.11.20210226) was used for analysis (22).

CT images of the people were loaded into the 3D Slicer program. The loaded images were reconstructed in 3D and oriented in three planes (Threshold Range= 200/3070 HU). Planes Ryckman et al. (23) was created based on. The horizontal plane was determined as the lowest border of the orbital bone with the bilateral porion point. The midsagittal plane was determined as the border passing through the sella and nasion perpendicular to the ground. Finally, the coronal plane oriented perpendicular to these two planes was created (Figure 2). The reference points we determined on the images were indicated as left and right, and their positions on the planes were confirmed (Table 1) (Figure 3,4,5). Measurements were made by a single person (NGC). One month later, the measurements of 10 randomly selected participants were re-evaluated (Intra-class correlation coefficient was used).

The asymmetry index gives information about the differences in body sides. In our study, the asymmetry index of the measurement results of the facial morphometry of both sides was calculated according to sex. Habets et al. (24) used the formula of Asymmetry Index= |(R-L) / (R+L)| * 100 (%) (AI: Asymetry Index, R: Right, L: Left). The values calculated with this formula provide a value for the symmetry/asymmetry specific to each individual by reducing extreme values to average values. As the calculated asymmetry index values moved away from zero, that region was considered asymmetrical.

Statistical Analyses

The data were evaluated in Statistical Package for the Social Sciences package program, version 26, IBM Corp., Armonk, New York, USA. Descriptive statistics were given as mean ± standard deviation (mean ± sd). The Pearson correlation coefficient evaluated the relationships between age and the measured and asymmetry index values of the face. According to sex, the face's measured and asymmetry index values were compared with the independent samples t-test. A value of $p<0.05$ was considered statistically significant.

RESULTS

A total of 90 individuals, 45 male and 45 female, were included in the study. The individuals were 18-57 years, and the mean age was 29.1±10.8 years.

CoGoMe_R˄ values of females were statistically higher than males ($p=0.049$). Although female's CoGoMe_L˄ values were higher than males, this difference was not statistically significant ($p=0.09$). The values of males were statistically higher than females in all other measurements ($p<0.05$) (Table 2).

According to the Pearson correlation test, a statistically significant weak positive correlation was found between age and right Condylion-Gonion-Menton angle (CoGoMe_R˄), left Condylion-Gonion-Menton angle (CoGoMe_L˄) ($r=0.228$, $p=0.031$ in both) and Condylion-Menton (CoMe) asymmetry ($r=0.237$, $p=0.024$). According to the Pearson correlation test, a statistically significant weak negative correlation was found between age and Condylion-Subspinale (CoSs) asymmetry ($r=-0.209$, $p=0.048$) (Table 3).

There was no statistical difference between the asymmetry index values of males and females ($p>0.05$) (Table 4).

DISCUSSION AND CONCLUSION

In the literature, many reasons cause facial asymmetry in humans. Various factors such as contralateral hemispheric control, development rates of facial muscles, genetic factors, weather conditions, gravity, bone resorption, and displacement of subcutaneous tissues cause asymmetry (25,26). Penke et al. (27) stated in

Table 1. Definition of the landmarks

Landmark	Definition
Condylion (Co)	Upper midpoint of the mandibular condyle
Gonion (Go)	The middle point of the part where ramus mandibula and corpus mandibula connect to each other
Menton (Me)	Symphysis is the lowest point of the mandible
Nasion (Na)	Midpoint of nasofrontal suture
Frontomalare orbitale (Fmo)	The junction of the zygomaticofrontal suture and the lateral edge of the orbit
Frontomaxillary (Fm)	Point where the frontomaxillary suture meets the medial edge of the orbit
Subspinale (Ss)	Point below the spina nasalis anterior
Supmentale (Sm)	The deepest point of the anterior alveolar bone recess in the mandible
Condylion-Gonion-Menton Angle (CoGoMeˆ)	Angle between Condylion, Gonion and Menton

Table 2. Comparisons between measured values of the face by sex

Variables		Sex		Test statistics†	
		Male	Female	Test value	*p*
Distance between Condylion-Gonion (*mm*)	R	64.891±5.372	56.495±4.925	7.729	***<0.001***
	L	64.970±6.257	56.621±4.521	7.256	***<0.001***
Distance between Gonion-Menton (*mm*)	R	85.286±5.284	77.975±5.657	6.336	***<0.001***
	L	83.996±4.825	77.896±6.369	5.122	***<0.001***
Condylion-Gonion-Menton (angle=ˆ)	R	117.989±4.749	119.901±4.460	3.975	***0.049****
	L	118.888±5.343	120.608±4.290	2.933	0.090*
Distance between Condylion-Menton (*mm*)	R	128.282±4.855	116.996±7.108	8.796	***<0.001***
	L	128.000±5.075	116.862±7.212	8.473	***<0.001***
Distance between Condylion-Nasion (*mm*)	R	105.718±4.109	97.972±3.661	9.443	***<0.001***
	L	105.165±3.890	97.675±3.177	10.004	***<0.001***
Distance between Condylion-Subspinale (*mm*)	R	102.812±3.922	95.324±4.535	8.378	***<0.001***
	L	102.228±4.102	95.352±4.635	7.453	***<0.001***
Distance between Frontomalare Orbitale-Frontomaxillary (*mm*)	R	38.558±1.481	36.467±2.409	4.958	***<0.001***
	L	38.709±2.029	36.689±2.104	4.636	***<0.001***
Distance between Frontomalare Orbitale-Menton (*mm*)	R	127.367±6.491	116.465±5.938	8.313	***<0.001***
	L	127.189±5.927	117.329±5.942	7.881	***<0.001***
Distance between Frontomalare Orbitale Right- Frontomalare orbitale Left (mm)		101.734±3.761	95.593±4.144	7.362	***<0.001***
Distance between Subspinale-Menton (*mm*)		60.783±5.936	55.166±3.887	5.310	***<0.001***
Distance between Nasion-Menton (*mm*)		123.053±7.625	110.261±6.378	8.632	***<0.001***

Data are given as mean±standard deviation. †: Independent samples *t* test, *: Adjusted for age. The parts determined in bold are statistically significant (p<0.05). R: Right, L:Left

their study that cognitive decline is associated with facial asymmetry. A deviation in the nasal septum in the middle of the face affects the development of many bone structures around it. Studies have reported that facial asymmetries occur due to developmental differences (28,29,30,31).

Studies in the literature report that the age factor affects the asymmetry. Soft tissues weaken with age (32), gravity reshapes the face with age (33), and repetitive contraction of facial muscles and redistribution of subcutaneous tissues over the years (34) are among the effects of age on asymmetry. Skomina et al. (35) reported that facial asymmetry increases, facial convexity decreases, forehead angle and distance between eyes increase with aging in both sex. Ferrario et al. (12) stated that facial asymmetry mainly was in adolescents, but there was no significant difference. Our study found a statistically weak positive correlation between age and CoGoMe_Rˆ, CoGoMe_Lˆ and CoMe asymmetry. A statistically weak negative corre-

Table 3. Correlations between age and variables

Variables	Age					
	Facial side				Asymmetry Index (%)	
	Right		Left			
	r	*p*	*r*	*p*	*r*	*p*
Distance between Condylion-Gonion (*mm*)	-0.003	0.980	-0.004	0.970	0.170	0.109
Distance between Gonion-Menton (*mm*)	-0.184	0.082	-0.193	0.069	0.111	0.297
Condylion-Gonion -Menton (angle=˄)	0.228	***0.031***	0.228	***0.031***	0.139	0.190
Distance between Condylion -Menton (*mm*)	-0.024	0.819	-0.014	0.894	0.237	***0.024***
Distance between Condylion-Nasion (*mm*)	-0.002	0.986	-0.043	0.685	0.072	0.498
Distance between Condylion-Subspinale (*mm*)	-0.096	0.370	-0.039	0.713	-0.209	***0.048***
Distance between Frontomalare Orbitale-Frontomaxillary (*mm*)	0.054	0.613	-0.028	0.794	-0.061	0.568
Distance between Frontomalare Orbitale-Menton	0.036	0.735	0.038	0.720	0.041	0.701

Variables	Age	
	r	*p*
Distance between Frontomalare Orbitale Right-Frontomalare Orbitale Left (mm)	-0.055	0.605
Distance between Subspinale -Menton (*mm*)	0.090	0.397
Distance between Nasion-Menton (*mm*)	0.080	0.454

r: Pearson correlation coefficient The parts determined in bold are statistically significant (p<0.05).

Table 4. Comparisons between Asymmetry Index Values by Sex

Variables	Sex		Test statistics†	
	Male	Female	Test value	*p*
Condylion-Gonion asymmerty (%)	1.475±1.139	1.656±1.155	0.749	0.456
Gonion-Menton asymmetry (%)	1.477±1.200	1.511±1.206	0.137	0.891
Condylion-Gonion-Menton asymmetry (%)	1.094±0.898	0.985±0.693	0.641	0.523
Condylion--Menton asymmetry (%)	0.924±0.718	0.891±0.668	0.055	0.815*
Condylion-Nasion asymmetry (%)	1.077±0.736	1.363±0.960	1.589	0.116
Condylion- Subspinale asymmetry (%)	1.856±1.496	2.210±1.738	1.103	0.297*
Frontomalare Orbitale -Maxillofrontale asymmetry (%)	1.630±1.302	1.762±1.091	0.523	0.602
Frontomalare Orbitale -Menton asymmetry (%)	0.735±0.625	0.819±0.885	0.522	0.603

Data are given as mean±standard deviation. †: Independent samples *t* test, *: Adjusted for age

lation existed between age and CoSs asymmetry. There was no statistically significant relationship between age and other facial measurements and asymmetry index values (p>0.05). In our study, it was observed that age mostly affected the measurements around the mandible. Various environmental factors cause mandibular height inequality. It is thought that this height inequality causes age-related measurements and asymmetry values. D'Antò et al. (36) study, CoGoMe˄ angle measurement was made on lateral cephalogram images of individuals aged 8-53. In the study, the average angle value of the Class I group was 127.09±7.8 and it was reported that it decreased by 0.6° every year with age. We think that the differences in findings are due to differences in methodology.

In previous studies, it has been reported that the facial width of males is greater than that of females in measurements made in the viscerocranium (37,38,39). Ferrario et al. (40) reported that males' faces were longer and wider than females' in their study, in which the basic face height was proportional to the width of the face according to the sex. Hodges-Simeon et al. (41) examined face length and width in their study. They said that because of the elongation in the lower face, the length of the face changes more than its width. It has been stated that this lower facial elongation is more prominent in males. Dividing the individuals in the 17-90 age group into three groups according to their age groups, Butovskaya et al. (42) explained sex differences in their regional studies. They named the 17-29

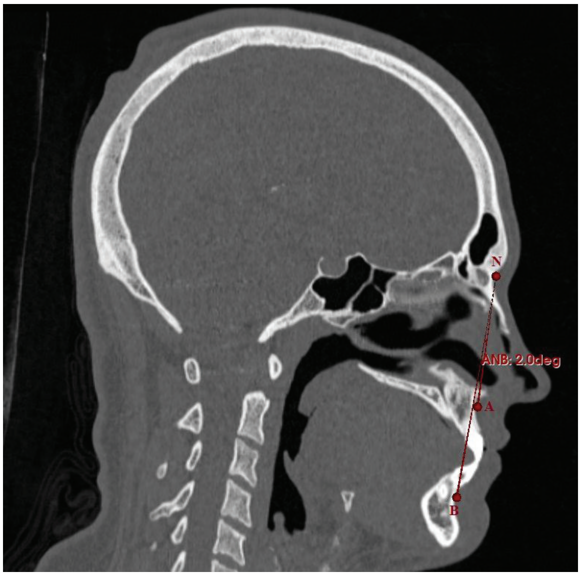

Figure 1. ANB (A: Subspinale, N: Nasion, B Supramental) angle view over sagittal section

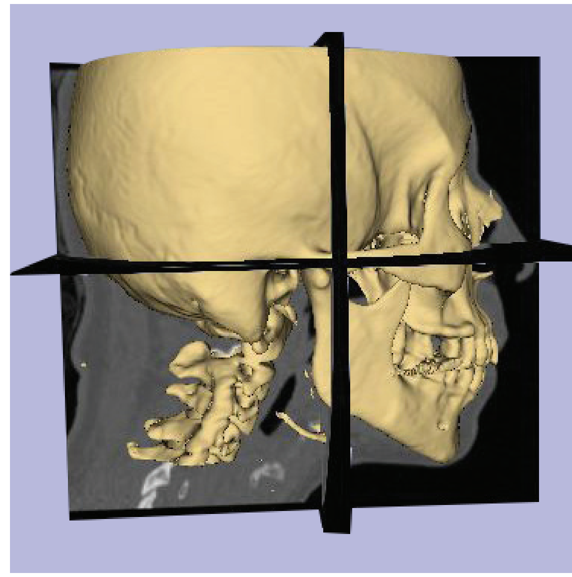

Figure 2. Planes used as a reference in the coordinate system

age group as the young group, the 30-50 age group as the middle group, and the 51 and over age group as the elderly. They stated that the sex differences in facial morphology were less in the younger age group, this difference increased with increasing age, but the sex difference in the elderly group was not significant. According to Skomina et al. (35), male faces were found to be more asymmetrical and wider, and it was stated that the difference between the sexes increased more in older adults. Toneva et al. (43) estimated sex from differences in shape and size in the viscerocranium. They argued that there was a significant difference in shape in all eye, nose, maxillary and zygomatic regions, and the sizes were significantly larger in males. Similarly, in our study, the measurements were higher in males than in females. Smith (44) reports in his study that the left sides of males and the right sides of females are wider than the opposite sides, but the difference is not significant. This difference may be due to differences in the cognitive processing of two different brain hemispheres. Ferrario et al. (12) divided the participants in their study into three groups adolescents, young adults and adults. They determined the points in the soft tissue of the face with an electromagnetic device and detected the asymmetries. They stated that there was no significant difference in the measurements and asymmetries depending on sex and that this asymmetry difference was higher in females of the same age group than in males. They reported that the greatest asymmetry values were in the adolescent group. They stated that tragion, gonion and zygion are the most asymmetric landmarks in the body. In our study, the facial morphometric measurements of males were found to be significantly larger than those of females, in line with the literature, in comparing face measurement values according to sex ($p<0.05$). Only CoGoMe_Lˆ did not differ significantly between sex ($p>0.05$).

Facial asymmetry is the deterioration of proportion and harmony on both sides of the face (2). Ferrario et al. (45) reported that the right side of the face is larger than the left side, while Maheswari et al. (2) stated that the left side of the face is larger than the right side in the vast majority of individuals with normal appearance. Peck et al. (46) reported that 3.54 mm of facial asymmetry was most frequently encountered in the mandibular region, followed by the zygomatic region (2.25 mm) and the orbital region (0.87 mm) respectively. Shaner et al. (47) reported that the normal limits of asymmetry in the upper and middle regions of the face were not more than 5 mm in males and 6 mm in females. In the lower regions, it was stated that the difference between the right and the left was 6 mm or more. Ferrario et al. (12) showed that this difference was at most 2.5 mm. In the same study, he reported that asymmetry, considered normal, is more common in females than males. On the other hand, Ercan et

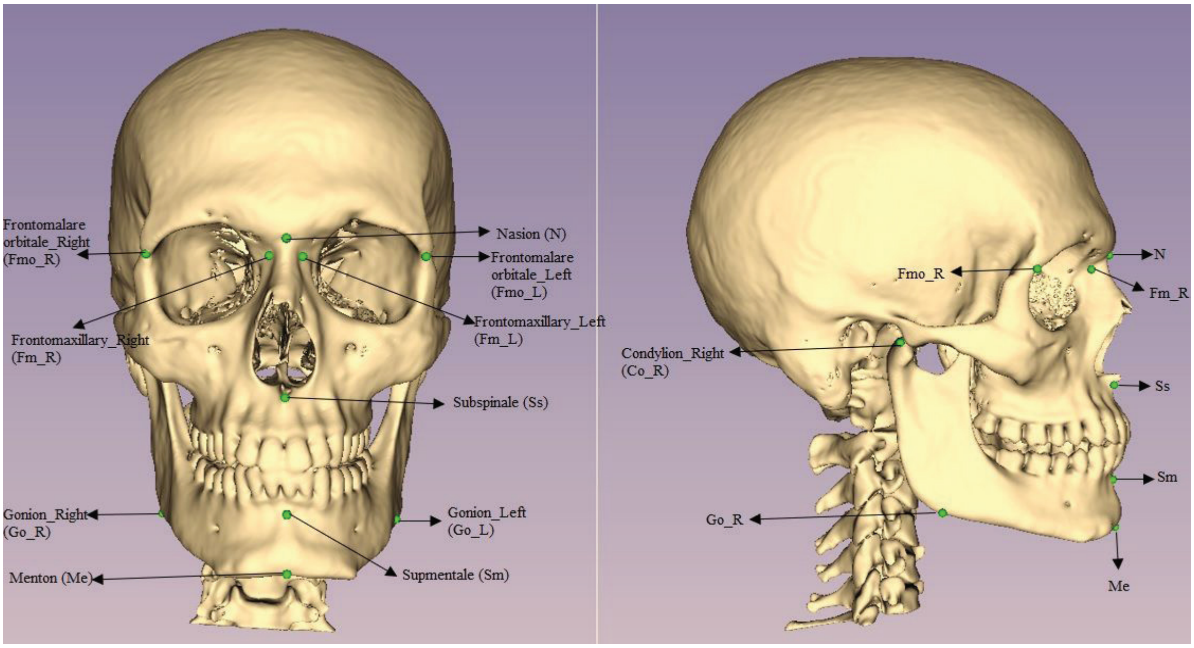

Figure 3. Front and right side view of landmarks

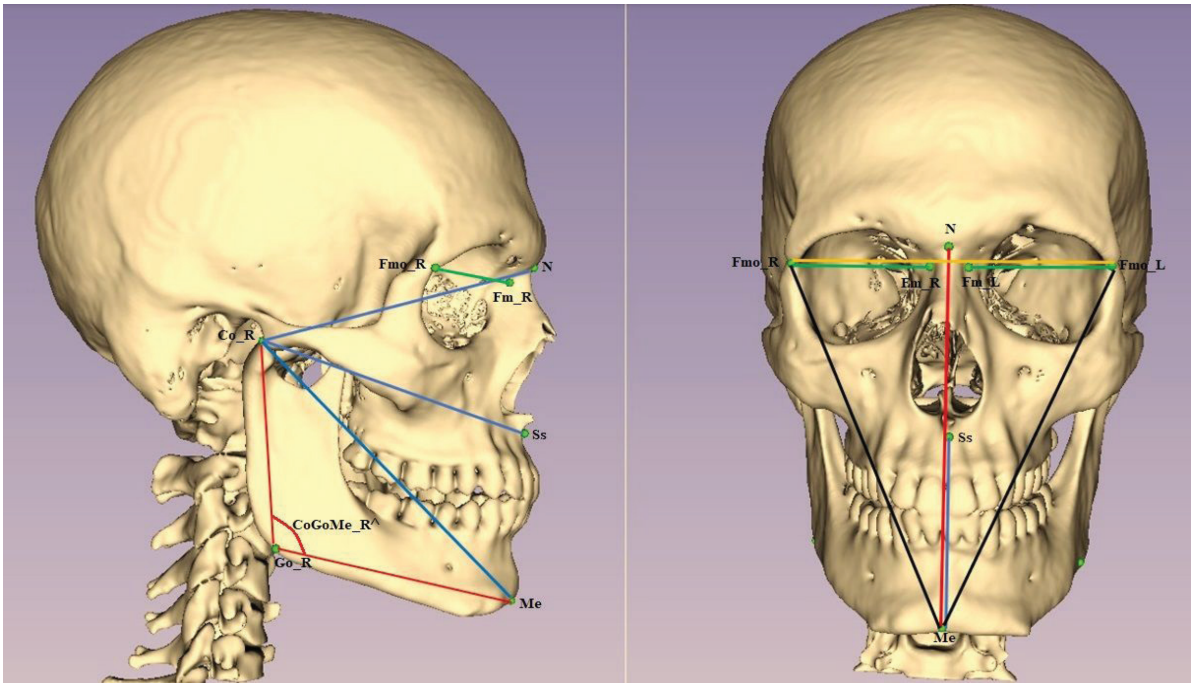

Figure 4. View of vertical and horizontal parameters together with the angle of the mandible (right side and front view) (Fmo_R: Frontomalare orbitale_Right, Fm_R: Frontomaxillary_Right, N: Nasion, Co_R: Condylion_Right, Go_R: Gonion_Right, Me:Menton, CoGoMe_R^: Condylion-Gonion-Menton_Right Angle, Ss: Subspinale Fmo_L: Frontomalare orbitale_Left, Fm_L: Frontomaxillary_Left)

al. (1) reported that asymmetrical differences on the right and left sides of the face were more common in females in their study of late adults, while Rajpara and Shyagali (13) emphasized that facial asymmetry is more common in males. Sajid et al. (48) also examined facial asymmetry by sex and ethnicity. They stated that asymmetry varies according to ethnicity, and males' faces are more asymmetrical than females'. In our study, it was determined that the asymmetry value did not differ according to sex. It is thought that our study

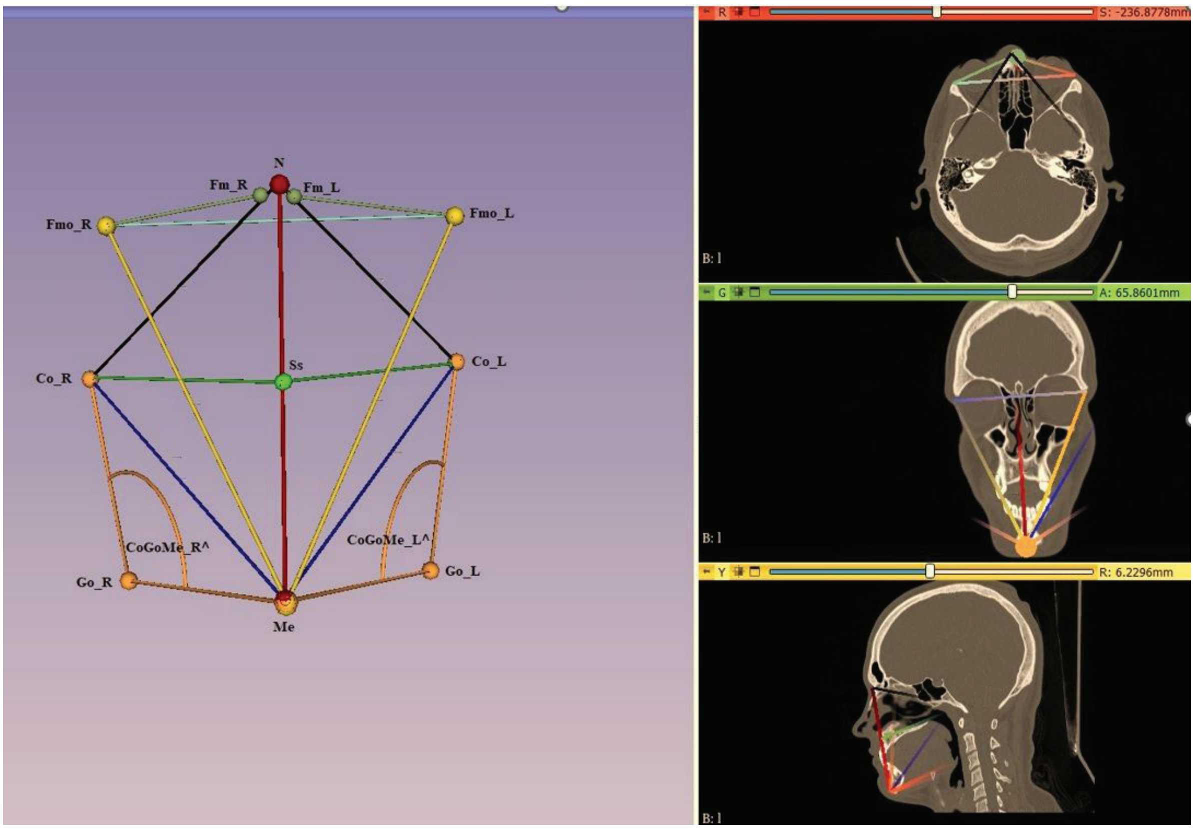

Figure 5. Geometric representation of anatomical measuring points (Fmo_R: Frontomalare orbitale_Right, Fm_R: Frontomaxillary_Right, N: Nasion, Co_R: Condylion_Right, Go_R: Gonion_Right, Me:Menton, CoGoMe_R^: Condylion-Gonion-Menton_Right Angle, Ss: Subspinale Fmo_L: Frontomalare orbitale_Left, Fm_L: Frontomaxillary_Left, Co_L: Condylion_Left, Go_L: Gonion_Left, CoGoMe_L^: Condylion-Gonion-Menton_Left Angle)

differs from the literature because of sample size, differences in asymmetry index calculations.

When the literature is examined, some researchers have calculated the facial asymmetry index by examining the face and marking certain points to evaluate the asymmetry with numerical data. There are different types of computation in various studies. Huang et al. (49) took 3D facial images of the participants. Sixteen facial signs were selected in each image, and they stated that the asymmetry in the lower parts of the face was more. Blasi et al. (50) calculated the facial asymmetry index with 3D-CT imaging. They found the asymmetry index in the lower third of the face to be higher than in the upper parts of the face.

Nakamura et al. (51) used PA cephalograms and front-view photographs to evaluate facial asymmetry and found the AI values with the calculated formula. Headache, neck stiffness or pain, and shoulder stiffness or pain compared the facial asymmetry index of the patient and healthy control groups. They could not find a significant difference (51). Our study found no significant difference when asymmetry values were compared according to sex ($p>0.05$). Of our results, Nakamura et al. (51) were found to be compatible with. We think this may be due to the similarity of the method we used to calculate the asymmetry index.

In recent years, 3D-CT imaging has overtaken the traditional cephalography-based method for a more detailed evaluation of facial asymmetry. Morphometric analyses and asymmetry index calculations are made to measure facial asymmetry. Our aim in this study was to determine the presence of asymmetry on both sides of the face, to make morphometric measurements according to sex/age, and to compare facial asymmetry index values according to sex. It is observed that the measurements around the mandible show more variation with age. In sex comparisons, although most of the facial morphometric measurements of males are significantly larger than females, there is no significant difference in the asymmetry index values. Correct detection and definition of reference points in the measurements made, especially the fact that the asymmetry index values are even at minimal levels, suggests the existence of asymmetry. For this reason, we believe that our study will be important for clinicians.

Limitations

Since our study is single-centered, it does not include different ethnicities, the sample size is small and analysis cannot be made by dividing it into age groups, and finally, since our study belongs to a healthy population and the ANB angle, which is an indicator of normal jaw development, is between 0-4°, can be considered as our limitation.

Conflict-of-interest and financial disclosure

The authors declare that they have no conflict of interest to disclose. The authors also declare that they did not receive any financial support for the study.

Author Contributions

N Gurlek Celik: Project development, data collection, data interpretation, visualization, writing- reviewing and editing. B Akman: Data collection, data interpretation, and approval of the version to be published. R Koca: visualization, writing- reviewing and editing and approval of the version to be published.

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