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RESEARCH ARTICLE

THREE-DIMENSIONAL EVALUATION OF FACIAL ASYMMETRY AMONG A SAMPLE OF YEMENI POPULATION: A CBCT STUDY

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Abstract

Background and aims: Facial asymmetry is an easily identifiable observation but is of great importance for both esthetics and function. In orthodontic and surgical planning a correct assessment of facial asymmetry is therefore indispensable. Aim of the present study was to measure three-dimensional skeletal facial asymmetry in the Yemeni population using CBCT and to analyze it by skeletal class and gender.
Methods: This is a retrospective study involving 62 Yemeni patients (22 males, 40 females) aged 14-40 years. Skeletal classification was according to ANB angles (Class I-III). Using the Slicer 3D software, 16 craniofacial landmarks were identified. 3D Slicer, as well as automated scripts in python was used for the determination of angular, linear and asymmetry indices. T-tests, ANOVA and Tukey post-hoc tests were performed for comparisons with significance set at p< 0.05.
Results: Mean skeletal asymmetry was found to be 3.46±1.01 mm, the mandible contributing to it largely in the gonial (4.04±1.94 mm) and antegonial (3.87±1.80 mm) regions and showing the minimum deviation in the maxilla. Higher values were observed for Menton deviation, gonial index, antegonial index, and overall skeletal asymmetry in Class III than Classes I and II (p<0.05). Higher mandibular dimensions and jugal asymmetry were evident in males than in females, although the global facial asymmetry did not show any significant sexual dimorphism.
Conclusions: The Yemeni population exhibited noticeable skeletal facial asymmetry where the mandible constituted the majority of it. The orthodontic assessment and surgical planning were highlighted by significant correlation between class III malocclusion and greater skeletal asymmetry.
Keywords: 3D cephalometry, CBCT, facial asymmetry, mandible, skeletal class.

INTRODUCTION

Facial symmetry is a prerequisite for craniofacial aesthetics and functional harmony. Although absolute bilateral symmetry is rare, any considerable asymmetry is a common aesthetic complaint, functional concern, and a psychological stressor[1]. The evaluation of facial asymmetry is integral part of diagnosis and treatment planning in orthodontics and maxillofacial surgery, especially in multi-ethnic populations such as Yemen with a mixed genetic background and environment[2]. Previously, it has been exclusively performed through 2D radiography (lateral and PA cephalograms) which measure the skeletal patterns and asymmetry but suffer from certain shortcomings like magnification, distortion, and superimposition of bilateral structures, obscuring fine asymmetrical values[3]. The Cone-Beam Computed Tomography (CBCT) has revolutionized the field of craniofacial imaging by enabling the acquisition of high-resolution 3D images of the craniofacial skeleton and dentition[4]. It provides a more accurate identification of cephalometric land-marks and derivation of reference planes, enabling more objective measurements and quantitative analysis of asymmetry in the sagittal, coronal, and axial dimensions[5]. In the context of Yemeni population, very few studies have been carried out till date to evaluate the pattern and prevalence of facial asymmetry in different skeletal classes using the 3D modalities which is necessary for the proper planning of orthodontic and surgical management in them[6].
The nature and extent of facial asymmetry have been related to the skeletal patterns, Class I, II and III, according to the relationship between the upper and lower jaw[7]. For example, studies on skeletal Class III malocclusion have generally recorded more prono-

unced mandibular asymmetry in compare to other skeletal classes[8]. Using CBCT-derived 3D imaging modalities, this study is aimed at giving a detailed descriptive analysis of the patterns of asymmetry present in Yemeni individuals and contribute in building up the craniofacial norm for different racial backgrounds and provide an index that helps in diagnosing patients with the above conditions[9].

MATERIALS AND METHODS

Study-design-and-population

This was a retrospective, cross-sectional, descriptive study investigating 3D skeletal facial asymmetry in a Yemeni population using pre-acquired CBCT scans. The study was conducted in Sana'a, Yemen, involving subjects from multiple ethnic groups. Of the 62 Yemeni subjects (22 men, 40 women; aged 14-40 years, mean age 19.7±5.0 years), all were included as they had all permanent teeth (except wisdom teeth), a high-quality CBCT scan and no previous orthodontic or orthognathic treatment. Subjects with congenital anomalies, significant trauma, tumours, nocentric relation during scanning or poor quality CBCT scans were excluded. Subjects were classified into skeletal Classes I, II, III according Steiner's based on ANB angle: class I (0 ≥ANB<4), class II(ANB≥4), class III (ANB<0).

CBCT-acquisition

CBCT scans were acquired from Al-Waleed Diagnostic Center on a Planmeca ProMax 3D Mid (voxel size 0.2–0.4 mm, 90 kVp, 10–14 mA, 12–15 seconds scanning time, FOV 20 cm x 17 cm) utilizing the Ultra Low Dose protocol.

Identification of landmarks

CBCT DICOM images were imported into the 3D Slicer (version 5.6.1) where 3D craniofacial models were produced. 16 anatomical points were located using multiplanar viewing and three orthogonal reference planes established (Figure 1) and were based on the literature[18,19]. The three reference planes were the Frankfort Horizontal (FHP) plane[20], Midsa-gittal plane (MSP)[21], and the Coronal Plane (CP) (Figure 2).

3D-analysis and measurements

To minimize measurement errors, an automated workflow mechanism was developed, the (x, y, z) coordinates for each landmarks were exported to a JSON file format and then processes them using a custom Python script for calculating: angles (SNA, SNB, ANB), reference planes, landmark-3 planes distances.

Quantification of asymmetry index

The custom Python script will also calculated asymmetric index of bilateral points (Co, Go, Ag, Jg) using the formula:

$$\sqrt{(Rdx - Ldx)^2 + (Rdy - Ldy)^2 + (Rdz - Ldz)^2}$$

Where the R (right), L (left), dx (distance from point to the MSP), dy(distance from the point to the Co), dz(distance from point to the FHP)[19]. For paramedial points (ANS, PNS, Me) measurements dx were used for calculated the deviation[19,22] and for calculated the discrepancies of mandibular ramus and body used the lineare distance between (Co-Go) for ramus height and the lineare distance between (Go-Me) for body lenght.

The inter side difference (Ramus diff / Body diff) were evaluated based on the absolute value of the difference between right and left (Ramus Height/Body Lenght)[23].

Reliability

Six CBCT scans randomly selected and were re-analysed after one month to assess intraobserver relia-bility (ICC >0.96).

Statistical analysis

Descriptive statistics (mean SD) were produced for the measured variables. Independent t-tests were used to compare means between genders and one-way ANOVA and Tukey's post hoc tests were used to compare skeletal Classes I, II and III (p<0.05).

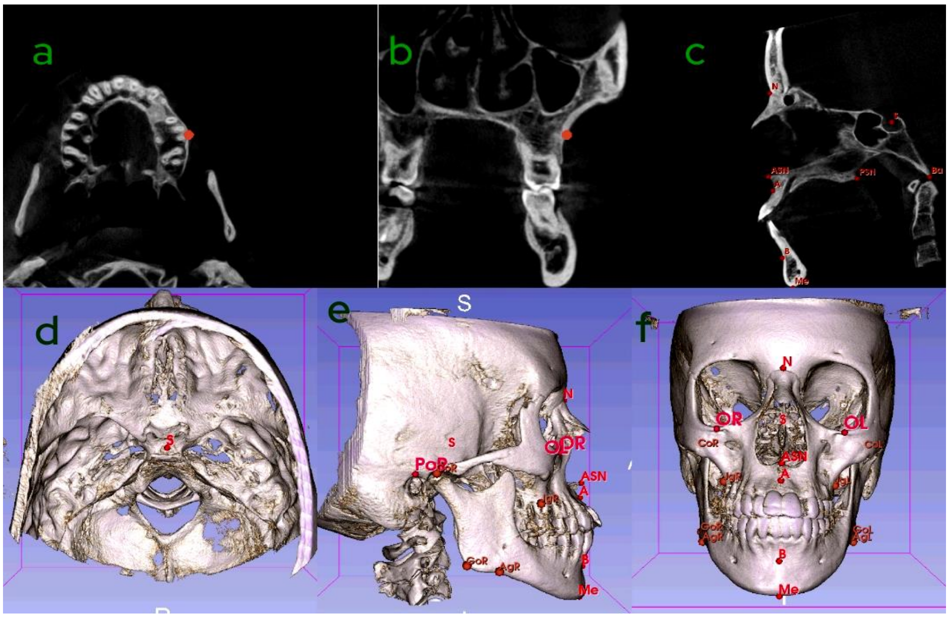

Figure 1: Landmarks identification Multi-planar and 3D Slicer view: (a) axial view, (b) coronal view, (c) sagital view and (d-f) reconstructed 3D view.

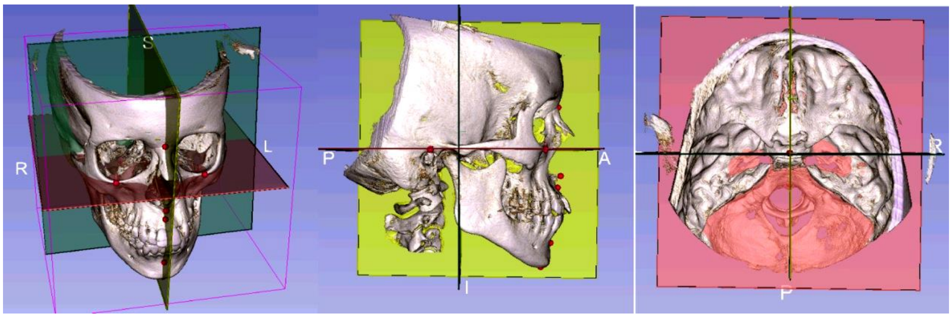

Figure 2: Construction of the 3D reference planes on the virtual skull model.

RESULTS

Sample characteristics

Table 1 lists the total number of Yemeni subjects (n=62), 22 males (35.5%) and 40 females (64.5%) ranging between the ages of 14 and 40 with a mean of 19.7±5.0 years. The majority pattern was skeletal Class II (46.8%) followed by Class I (38.7%) and skeletal Class III (14.5%). The overall mean ANB was 3.71 3.49 showing high variability in skeletal sagittal relationships.

Table 1: Demographic and skeletal characteristics of the sample (N = 62).

Category	Group	N (%)
Sex	Male	22 (35.5%)
	Female	40 (64.5%)
Age (Year)	Total	19.7±5.0
Skeletal classification	Class I	24 (38.7%)
	Class II	29 (46.8%)
	Class III	9 (14.5%)

Table 2: Key descriptive statistics of asymmetry variables.

Variable	Mean±SD (mm)
Menton deviation	1.69±1.29
ANS deviation	0.64±0.47
PNS deviation	0.64±0.64
Co index	3.31±1.60
Go index	4.04±1.94
Ag index	3.87±1.80
Jg index	2.62±1.03
Ramus diff	1.7±1.39
Body diff	1.39±1.11
Overall asymmetry	3.46±1.01

Descriptive analysis of facial asymmetry

As shown in Table 2, the mandibular landmarks, especially in the gonial (Go) and antegonial (Ag) region, showed the highest asymmetry. In terms of the maxillary midline landmarks (ANS, PNS), there were very few differences. The total asymmetry was 3.46± 1.01 mm, which suggests a moderate amount of skeletal asymmetry within the subjects.

Dimorphism in asymmetry and cephalometrics

Table 3, shows a comparison of male and female for all variables using independent samples t-tests, a statistically significant were identified for some of the mandibular landmarks for Ramus difference and body difference, in the male (2.22±1.47 mm) and (2.04± 1.39 mm) is larger than in the female (1.42± 1.27 mm) (p=0.028) and (1.03±0.73 mm)(p<0.001). Significant differences between male and female is present in jugale (Jg) index of maxillary, which was larger in males (3.03±1.05 mm) than females (2.40±0.96 mm) (p=0.021).

Influence of skeletal classification on facial asymmetry

Table 3, One-way ANOVA indicated that significant differences were present in terms of the Skeletal Classes for Menton deviation, Go Index, Ag Index, and Overall Asymmetry (p<0.05). Skeletal class III exhibited higher values in terms of asymmetry in all variables than other skeletal classes. According to the post-hoc test, the differences in chin deviation, gonial and antegonial asymmetry, and overall asymmetry in skeletal class III are statistically larger than those in skeletal classes I and II. Tukey HSD post hoc analysis between group differences show a significant differrence for menton deviation between class III and class I (Mean difference=1.67, p=0.002) and class II (Mean difference=1.67, p=0.001), also significant difference between class III regard to Ag index (Mean difference =2.54, p<0.001) for class I and (Mean difference =2.52, p<0.001) class II. A significant difference also between class III and class I with regard to Go index (Mean difference=1.98, p=0.022).

Table 3: Gender differences across all variables (independent t-test)

Variable	Male	Female	*p*-value
Me deviation	1.75±1.35	1.66±1.27	0.793
ANS deviation	0.67±0.43	0.63±0.49	0.703
PNS deviation	0.73±0.60	0.60±0.66	0.456
Co index	3.26±1.41	3.34±1.71	0.848
Go index	4.48±2.30	3.79±1.69	0.182
Ag index	3.73±2.15	3.94±1.60	0.665
Jg index	3.03±1.05	2.40±0.96	0.021*
Ramus diff	2.22±1.47	1.42±1.27	0.028*
Body diff	2.04±1.39	1.03±0.73	<0.001*
Overall asymmetry	3.63±1.16	3.37±0.91	0.341

* Significant at p<0.05

Table 4: ANOVA asymmetry according to skeletal classification and Post-hoc Tukey HSD for significant parameters.

Variable	Class I (Mean±SD) significant *p*- value	Class II (Mean±SD) significant *p*- value	Class III (Mean±SD)	*p*-value
Ramus diff (mm)	1.82±1.47	1.75±1.34	1.22±1.31	0.426
Body diff (mm)	1.38±1.20	1.31±1.02	1.66±1.21	0.259
Me dev (mm)	1.45±0.95 (0.002)a*	1.45±1.16 (0.001)b*	3.12±1.65	<0.001*
ANS dev (mm)	0.58±0.47	0.64±0.48	0.81±0.41	0.506
PNS dev (mm)	0.67±0.66	0.65±0.66	0.55±0.55	0.557
Co index (mm)	3.20±1.40	3.21±1.57	3.96±2.19	0.310
Go index (mm)	3.34±1.33 (0.022)a*	4.21±1.95	5.33±2.63	0.024*
Ag index (mm)	3.49±1.56 (<0.001)a*	3.51±1.44 (<0.001)b*	6.03±2.08	<0.001*
Jg index (mm)	2.47±1.04	2.62±1.10	3.03±0.83	0.335
Overall asymmetry	3.23±0.76 (<0.001)a*	3.30±0.87 (0.001)b*	4.59±1.30	<0.001*

* Significant at $p < 0.05$ between all class, a* significant at $p< 0.05$ between class I and, III, b* significant at $p< 0.05$ between class II and, III.

Regional contribution to facial asymmetry

A marked asymmetry was seen regionally in both the maxilla and mandible. In fact the disparity in asymmetry between the mandible (2.67±0.98 mm) and maxilla (1.30±0.44 mm) was found to be statistically significant (p<0.001), and thus the mandible can be shown to be the primary skeletal contributor to facial asymmetry.

DISCUSSION

The comprehensive data that arise from the well-executed present study provide us with an excellent overview of the craniofacial asymmetries present within the Yemeni population. With a mean age of 19.7±5.0 years, the majority of the subjects can be said to be adults, where all craniofacial growth is completed and accurate assessment of skeletal asymmetry can be established[7]. The subjects were also disproportionately represented in the female gender (64.5%) which is expected, as esthetics are a greater concern to females and orthodontic and maxillofacial patients are thus more prone to seek orthodontic treatment, similar to a study previously done in Yemeni adults[6].

The skeletal patterns presented included majority skeletal Class II (46.8%) and the next most common skeletal Class I (38.7%) and the least common, skeletal Class III (14.5%, This distribution aligns with established clinical observations and orthodontic and orthognathic epidemiological data, where Class II malocclusions frequently constitute the largest portion of patients seeking treatment in secondary and tertiary referral centers. This finding is consistent with the a previous study[24], and which is verified by the Mean ANB value of 3.71±3.64 which shows that a multitude of skeletal discrepancies exist within this sample[10]. The SNA and SNB means were largely within normal limits of average skeletal measurements. Thus the skeletal patterns are overall average skeletal relations however there is large variability within the range for ANB which verifies the wide variety in skeletal discrepancies[11]. The average values of skeletal landmarks showing overall asymmetry (3.46±1.01 mm), with mandibular land-marks being the most asymmetric (Go and Ag) is consistent with most of the researches. Many authors are convinced of the existence of some degree of asymmetry in most faces and it is usually believed to be within a normal biologic range[25,26] and the mandible is the most frequently observed asymmetric facial skeleton[27,28]. The significant difference shown between mandibular (2.67±0.98 mm) and maxillary (1.30±0.44 mm) asymmetry (p<0.001) reinforces this widely accepted concept that mandi-bular component has more impact in facial profile symmetry than maxillary part. Our findings, revealing statistically significant difference for sexual dimorphism (p=0.028 and p<0.001 for ramus difference and body difference respectively and p=0.021 for Jg Index) further corroborate this notion of larger mandibular skeletal dimension among male, similar results were obtained by Yagnesh *et al*[35].

Studies have revealed sexual dimorphism of mandibular measurements with significantly larger size in males than females across the spectrum of popul-ations studied such as Egyptian and Saudi[29,30], and another studies proves gender dimorphism is important to lower jaw asymmetry[7,12]. The reason for this is thought to be the difference in gonadal hormone concentrations during adolescence where males experi-ence greater growth spurt and bone deposition. While some of the researches show no significant influence of gender over perception of facial asymmetry[31] but actual skeletal discrepancy measure-ments shows sex difference in almost all studied regions of face except for soft tissues and sometimes specifically in mandi-bular region[32]. Our data clearly indicates that the Skeletal Class has a significant impact on the overall facial asymmetry with Skeletal Class III patients having more significant disparity for chin deviation, Go and Ag indices and overall asymmetry as compared to Skeletal Class I and Class II patients (p<0.05) and this observation is strongly supported by some researches[33,34]. The increased asymmetry seen in Class III malocclusion is due to its underlying prognathism and disproportionate growth of mandible leading to compensations. Post-hoc analysis also proved that Chin deviation, gonial index, antegonial index and overall asymmetry were significantly larger for Skeletal Class III than for class

II patients. Thus, this comparative discussion highlights that some of our observations agree with established patterns whereas others seem to have some distinct characteristics like skeletal class distribution, thereby providing an insight to a variation among Middle Eastern populations, it also confirms the prominent role of the mandible in overall facial symmetry along with the existing differences regarding sex and skeletal class. This knowledge is necessary for defining population specific normal values and planning for successful treatment strategy in orthodontics and maxillofacial surgery. Longitudinal and genetic studies should be conducted to clarify the etiology for these differences found in Yemeni people.

Limitations of the study

The study was characterized by a relatively small number of subjects, specifically for the skeletal Class III group, which might have influenced the statistical significance and reliability of the data presented. The retrospective, cross-sectional nature of this study failed to assess the longitudinal craniofacial growth changes or progress of the asymmetry over time. The examination included the skeletal hard tissues structures only in the CBCT, and omitted the facial soft tissues asymmetry, as well as the functional aspects such as the muscle function and the TMJ behavior.

CONCLUSIONS

The purpose of this retrospective study was to quantitatively determine the magnitude and distribution of 3D skeletal facial asymmetry in the Yemeni population for skeletal Classes I, II, and III. We used a protocol to quantify 3D skeletal facial asymmetry using CBCT, 3D Slicer software, and automatic Python based calculation to ensure accurate identification of craniofacial landmarks. The study showed that in Yemeni individuals, skeletal facial asymmetry was a common finding; skeletal Class I was the highest predictor and the mandible seemed to be the dominant contributor to skeletal facial asymmetry with emphasis on the gonial and antegonial region while themaxillary components were negligibly asymmetrical. In general, there was a mild to moderate degree of asymmetry within the Yemeni population, however, subjects with Skeletal Class III were significantly more asymmetrical compared to the others. The Mandibular deviation in Menton, gonial index, and antegonial index were much larger in class III, thus confirming that mandibular prognathism and transverse asymmetry correlate well. Looking at the sex differences, while the overall score showed no sex difference in degree of skeletal facial asymmetry, the ramus height and the length of the mandibular body were significantly larger in males. The jugale index of the maxilla was also significantly greater in the male subclass. Through correlation analysis, lower facial landmarks at the gonion and antegonion had the strongest predictive value for total facial asymmetry. Overall, this paper provides important 3D skeletal facial asymmetry norms in the Yemeni population that can be used as diagnostic reference in the diagnosis of orthodontic and orthognathic surgery and treatment planning by orthodontists and maxillofacial surgeons.

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AUTHOR’S CONTRIBUTIONS

Al-Rahbi LM: formal analysis, conceptualization, data organization, and clinical and laboratory examinations. **Jasar YY:** conceptualization, data organization, supervision. **Al-Ashwal AA:** conceptualization, data organization. **Jahaf MYM:** critical review. Final manuscript was checked and approved by both authors.

DATA AVAILABILITY

The empirical data used to support the study's conclusions are available upon request from the corresponding author.

CONFLICT OF INTEREST

None to declare.

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