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Sagittal discrepancies of the jaw in a Bangladeshi cohort: three-dimensional computed tomography analysis

Mushrath Islam[1,*], Ayman Hameed Uraibi[2], Arkan Al Azzawi[3], Mohammad Khursheed Alam[4,*] and Asilah Yusof[5]

Abstract

Objectives: In orthodontic diagnosis and treatment planning, the assessment of skeletal jaw relationships is an essential step. This study aimed to evaluate skeletal jaw relationships in a Bangladeshi cohort by using traditional (ANB angle and Wits appraisal) and newly described (Beta angle, W angle, and Yen angle) sagittal measurements in three-dimensional (3D) computed tomography (CT).

Methods: The radiology department conducted CT scans of Bangladeshi patients. Mimics 3D imaging software (Materialise) was used to process the CT images and evaluate 3D sagittal measurements. SPSS software (IBM) was used to assess significant differences in the data at a confidence level of 5%. Independent-samples t-tests were used to evaluate sexual dimorphism for the measured values.

Results: In total, 85 men and 32 women were included in this study. All measurements were equivalent to the existing standards. There were no significant differences in the acquired values between men and women. Measurements were consistent with Class I normal classification.

Conclusions: This study established 3D CT standards for ANB, Wits appraisal, Beta angle, W angle, and Yen angle in Bangladeshi patients.

[1]Orthodontic Unit, School of Dental Science, Universiti Sains Malaysia, Kelantan, Malaysia
[2]Oral and Maxillofacial Surgery Department, College of Dentistry, University of Babylon, Hilla, Iraq
[3]Orthodontic Department, College of Dentistry, University of Babylon, Hilla, Iraq
[4]Orthodontic Department, College of Dentistry, Jouf University, Sakaka, Kingdom of Saudi Arabia
[5]Craniofacial Morphology Unit, School of Dental Science, Universiti Sains Malaysia, Kelantan, Malaysia

*These authors contributed equally to this work.

Corresponding authors:
Asilah Yusof and Mohammad Khursheed Alam, School of Dental Science, Universiti Sains Malaysia. Kubang Kerian 16150, Kota Bharu, Kelantan, Malaysia; Orthodontic Department, College of Dentistry, Jouf University, Sakaka, KSA.
Emails: asilah@usm.my; dralam@gmail.com

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Introduction

The core aim of orthodontic treatment is to enhance the patient's skeletal, dental, and soft tissue structure.[1] Accurate anteroposterior measurement of jaw relationships is essential for patients and their families. For analysis and treatment planning in orthodontics, assessments of maxillary and mandibular positions in the sagittal plane are necessary to understand the craniofacial morphology of any population.[2]

Wylie[3] initially described skeletal sagittal analysis. Subsequent investigations applied various parameters, such as the ANB angle,[4] Wits appraisal,[5] and Beta angle (recently described)[6] to measure maxillary-mandibular disharmony. However, these parameters have unique limitations. Rotation of the jaws during growth or orthodontic treatment and stability of the nasion can affect the ANB reading.[5,7,8] Wits appraisal reduces the rotational effects of jaw growth by using the occlusal plane—a dental parameter—to define skeletal discrepancies. However, the occlusal plane can be exaggerated by tooth eruption and dental development, as well as orthodontic treatment.[9–11] Moreover, Wits appraisal exhibits difficulty in finding the functional occlusal plane in a variety of patients.[12,13] The Beta angle uses condyles to assess sagittal discrepancy, which is not a genuinely reproducible landmark.[6,14] The newly introduced W and Yen angles are reportedly more dependable because they use stable landmarks (e.g., Sella, G-point, and M-point).[15]

Cephalometrics has been widely used for the evaluation of jaw relationships in orthodontics.[16] Unfortunately, data obtained from cephalometric radiographs may exhibit geometric distortion and superimposition of structures on radiographs. Moreover, cephalometrics involves two-dimensional (2D) rendering of a three-dimensional (3D) structure; thus, data may exhibit projection, landmark identification, and measurement errors.[17] Three-dimensional imaging modalities used in dentistry include computed tomography (CT) and cone beam computed tomography (CBCT). CT scans enable "cut by cut" examination of internal human anatomy via computer transformation of radiographic pictures;[18] notably, craniofacial structures can be viewed without superimposition of anatomical structures.[19,20] Numerous imaging software programs enable 3D recreation of 2D pictures, facilitating examination of craniofacial structural difficulties and enhancing treatment planning.[21]

A few previous studies have shown CBCT-based cephalometric norms for Korean,[22] Indian,[23] and Turkish[24] cohorts. To the best of our knowledge, no 3D CT data have been published regarding sagittal discrepancy measurements. In Bangladeshi cohorts, craniofacial morphology has been surveyed by using traditional cephalometric analysis methods,[25,26] but not by 3D CT sagittal analysis. This study aimed to assess 3D CT sagittal discrepancies of the jaw relationships by applying traditional and newly described sagittal measurements.

Methods

Study design

This cross-sectional study enrolled Bangladeshi patients who underwent CT scans at the Radiology Department of Medinova Medical Services Ltd. Patients underwent CT scans for reasons other than craniofacial abnormalities (e.g., severe headaches, changes in mental status, or migraines). The inclusion criteria for the investigation were age 18 to 65 years, no history of plastic or reconstructive surgery, and high-quality CT volumetric information. Patients with craniofacial malformations, cleft lip, cleft palate, wounds, burns, or scar tissues in the craniofacial area, as well as patients with a history of orthodontic treatment, were excluded from the investigation.

Ethical approval

Patients provided written informed consent prior to undergoing CT scans, and the consent forms were reviewed and approved by the ethical authority of our institution. Data were gathered from the archive with the best possible consent from the authority for research uses. All research-related work in this study was performed in the School of Dental Science, Hospital Universiti Sains Malaysia (HUSM). Approval for this study (USM/JEPeM/16080251) was obtained from the Human Research and Ethics Committee of the Universiti Sains Malaysia.

Imaging protocol and selection

PS Software version 3.0.43[27] was used for sample size calculation for male and female patients, with power = 80%, alpha = 0.05, mean difference = 2 mm, ratio = 1:2.5, and estimated standard deviation = 4.81 mm. The calculated sample sizes were 32 female patients and 85 male patients. The patients were chosen based on inclusion and exclusion criteria from a pool of 160 head-and-neck CT scans. The final CT scans were selected by using a simple random sampling technique (lottery method).

CT images were gathered from the CT database archive from the year 2015 to 2016. These scans were high-resolution helical scans, obtained using the General Electric Light Speed Plus Discovery VCT 128-slice CT Scanner System (GE Healthcare, Milwaukee, WI, USA) using standard procedures. The CT resolution was set at thickness of 1.25 mm and spacing of 1.25 mm. The tube voltage and current were 120 kV and 150 mA, respectively. The settings were balanced further as needed to adjust for the patient's weight.

CT scans were maintained in DICOM format, moved to a personal computer, and then imported into the Mimics medical imaging software (version 11.02, Materialise, Leuven, Belgium). Mimics software was also used to construct 3D images from 2D cross-sectional images. A series of modifications were made to the CT data, including thresholding, region growing, and editing; these are described in detail below.

Image analysis

Segmentation of CT data was performed to measure a region of interest (e.g., the outer craniofacial portion or the inner portion of the skull). The patient's head was oriented such that the Frankfort horizontal plane was parallel to the lower border of the screen display in both sagittal and coronal projections (Figure 1a). CT data were converted to a "mask" by using a threshold technique in which a line on a 2D image (drawn using the "Profile Line" feature) identified the particular threshold values that varied along the line. The threshold level was used to determine the minimum density of material to be included in a 3D-CT reconstruction. This scan was reconstructed at a threshold value that distinguished bone from soft tissue and air (Figure 1b). Region growing was applied to select only the region of interest. Other regions with the same "mask" value could

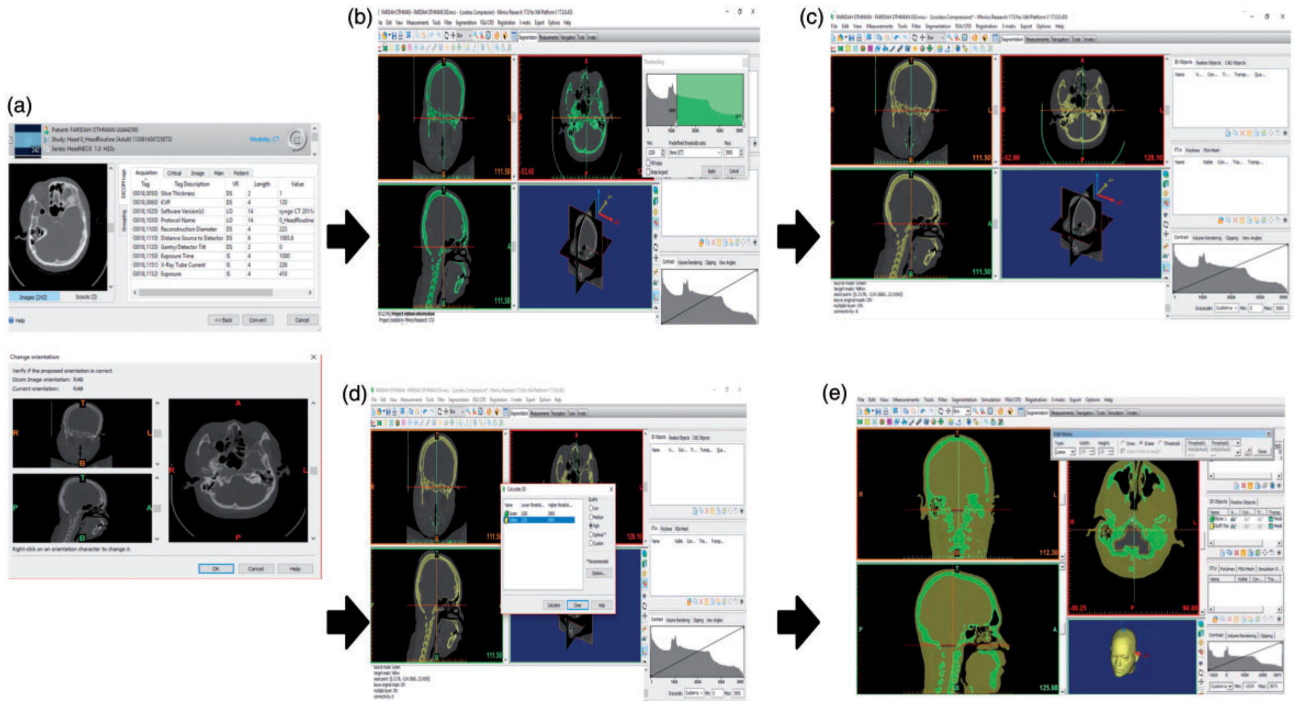

Figure 1. Overall workflow for conversion of two-dimensional (2D) images to three-dimensional (3D) images in Mimic software. (a) Segmentation and changes in the orientation of the computed tomography data. (b) Application of threshold technique in Mimic software. (c) Application of region growing to choose only the region of interest. (d) Conversion of CT images from 2D to 3D by using calculate 3D tool. (e) Mimics software enables 2D axial, sagittal, and coronal views, as well as 3D reconstruction of images. Measurements were performed on 3D images with the aid of other 2D views.

be removed easily by use of the region growing method to ensure that the target region only was selected (Figure 1c). Subsequently, the 2D images were converted to 3D images by using the "calculate 3D" tool (Figure 1d). This software enabled 2D sagittal and axial views, as well as 3D reconstruction of the images. Measurements were performed on the 3D images with the aid of other 2D views (Figure 1e).

3D image-segmentation within Mimics software was used to measure parameters from the identified landmark points (Table 1). The Frankfort Horizontal (FH) plane was used to select landmarks on 3D images and then confirmed on the mid-sagittal plane. A single operator performed all of the following measurements in accordance with previously published methods (Figure 2).

Table 1. Identified landmarks and their definitions.[21,35,36]

Landmark	Name	Definition
N	Nasion	Junction between nasal and frontonasal sutures.
S	Sella	Center of sella turcica on midsagittal plane.
A	Point A	Deepest point between ANS and prosthion at midsagittal plane.
B	Point B	Deepest point between pogonion and alveolus of lower incisors on midsagittal plane.
M	Maxillary point	Mid-point of premaxilla.
C	Point C	Center of condyle.
G	Point G	Center of mandibular symphysis.

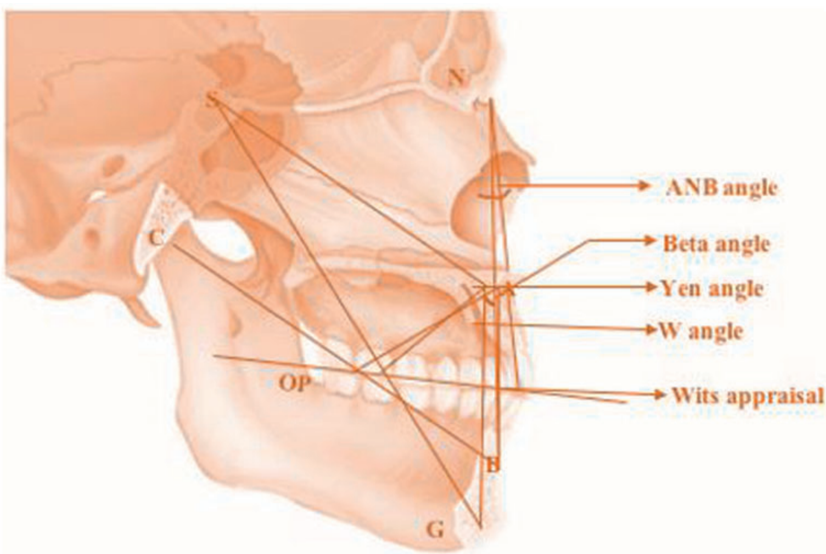

Figure 2. Three-dimensional computed tomography analyses performed in the sagittal plane: ANB angle, Wits appraisal, Beta angle, W angle, and Yen angle.
Abbreviations: N, Nasion; S, Sella; A, Point A; B, Point B; C, Point C; G, Point G; OP, occlusal plane.

ANB angle: the angle involving three points (A, N, and B) on the mid-sagittal plane.[28]

Beta angle: a line drawn from the center of the condyle to point B (C–B). A separate line was drawn from point A perpendicular to the C–B line. The Beta angle is the angle between this perpendicular line and the A–B line.[6]

W angle: the Sella is associated with a midpoint of the pre-maxilla (S–M line) and the focal point of the mandibular symphysis (S–G line). A perpendicular line is drawn from point M toward the S–G line. The W angle is the angle between this perpendicular line and the M–G line.[15]

Yen angle: the angle between the M–G line and the S–M line.[29]

Wits appraisal: the horizontal distance between AO and BO lines oriented perpendicularly from the starting point A and point B toward the functional occlusal plane.[5]

All measurements were repeated three times. The second measurements were conducted after 2 weeks, and the researcher was blinded to the outcomes to limit bias. The third measurements were performed 2 weeks after the second measurements; these were also performed in a blinded manner. The midpoints of the three readings of each measurement were used for statistical analysis with the specific end goal of limiting intra-examiner variation.

Statistical analysis

Data gathered by the researchers were initially recorded in Excel (version 14.0, Microsoft Corp., Redmond, WA, USA). Statistical analyses were performed using SPSS software (version 22.0, IBM Corp., Armonk, NY, USA). Descriptive statistics such as mean values, standard deviations, standard errors, and coefficients of variation were generated separately for men and women. Normality of the data was assessed using the Kolmogorov–Smirnov test. An independent-samples t-test was used to compare the mean measurements between men and women. P-values < 0.05 were considered to be statistically significant.

Results

The Kolmogorov–Smirnov test showed that all data were normally distributed. Intraclass coefficient analyses revealed intra-examiner reliability values of 0.90–0.96; thus, the examiner's measurements were reliable. The study sample comprised 85 men and 32 women. Traditional and newly described sagittal measurements, along with their normal values, are presented in Table 2. All measurements were within the established normal ranges. There were no significant differences in the measurements between men and women. All measurements were consistent with Class I normal classification.

Discussion

Precise anteroposterior measurement of jaw relationships is essential in orthodontic treatment planning. Both angular and linear variables have been proposed to describe sagittal jaw relationships and jaw positions. Angular measurements can be influenced by changes in facial height, jaw inclination, and aggregate jaw prognathism; linear variables can be influenced by the inclination of the reference line.[30] Although multiple examinations are available to measure maxillary-mandibular disharmony, all exhibit unique limitations; new methods have thus been introduced to overcome the limitations of the traditional methods. To the best of our knowledge, this is the first analysis of the craniofacial morphology of a cohort of Bangladeshi patients using 3D CT in the sagittal plane with both traditional and newly described measurement methods.

Measurements in the present study were compared with Pakistani,[31] Malaysian,[32] Malaysian Chinese,[32] and Turkish[33] cohorts

Table 2. Sagittal measurements of men (n = 85) and women (n = 32) in this study.

Variable	Sex	Mean	SD	95% CI Lower	95% CI Upper	p-value	Normal range
ANB (°)	Male	2.80	1.639	−0.188	1.094	0.154	2°–4°
	Female	2.35	1.325	−0.134	1.040		
Beta (°)	Male	30.79	1.082	−0.154	0.704	0.206	27°–35°
	Female	30.52	0.933	−0.129	0.679		
W (°)	Male	55.86	2.925	−0.497	1.736	0.274	51°–56°
	Female	55.24	2.053	−0.340	1.579		
Yen (°)	Male	120.44	4.425	−1.196	2.110	0.585	117°–123°
	Female	119.99	2.645	−0.874	1.788		
Wits appraisal (mm)	Male	0.96	0.436	−0.168	0.192	0.896	−3–0
	Female	0.95	0.449	−0.173	0.197		

p-values represent comparison by independent-samples t-test.
Abbreviations: ANB, A–Nasion–B angle; SD, standard deviation; CI, confidence interval.

Table 3. Comparisons of sagittal measurements of the Bangladeshi cohort with those of other cohorts.

Cohort	Subjects (n)	ANB angle (°)	Beta angle (°)	W angle (°)	Yen angle (°)	Wits appraisal (mm)
Pakistani	209	3	28	53	117	2
Malaysian	246	3.41	33.25	53.08	117.98	0.21
Malaysian Chinese	96	3.95	34.74	53.22	118.18	0.87
Turkish	145	2.79	0	0	0	0.44
Bangladeshi (present study)	118	2.8	30.79	55.86	120.44	0.96

(Table 3). All other studies used cephalometry as their research tool. Comparisons were possible for only a portion of the sagittal measurements because the other studies performed few measurements similar to those of the present study; these were the ANB angle, Beta angle, W angle, Yen, angle and Wits appraisal. Compared with the other cohorts, the present study demonstrated the smallest ANB angle (2.8 degrees), while the Malaysian Chinese demonstrated the largest ANB angle (3.95 degrees). All cohorts had ANB angles within the established normal range. Similarly, the Beta angles of all cohorts were within the normal range. Norms for the Beta angle were established for the Pakistani (28 degrees) and Malaysian (33.25 degrees) cohorts; in our study, the norm was 30.79 degrees, which was between the norms for the Pakistani and Malaysian cohorts. In addition, the W angle was 53 degrees for the Pakistani cohort and 53.22 degrees for the Malaysian Chinese cohort; in our study, it was 55.86 degrees, which was slightly larger than that of the other cohorts, but remained within the normal range. Norms for the Yen angle were established for the Pakistani (117 degrees) and Malaysian Chinese cohorts (118.18 degrees); in our study, it was 120.44 degrees, which remained within the normal range. Wits appraisal in the present study was similar to that in the Malaysian Chinese and Turkish cohorts; the Pakistani cohort showed the greatest Wits appraisal value (2 mm). These differences among Pakistani, Malaysian, Malaysian Chinese, and Turkish cohorts, with respect to the present study values, are likely because each cohort demonstrated variations in jaw characteristics, size, shape, and growth. The differences may also derive from complex interactions of genetic and environmental factors. Therefore, standards should not be applied without validation among ethnic groups or subgroups.

Measurements of the ANB angle in the present study were similar to the norms established by Steiner;[28] the measurements of Wits appraisal were also similar to the original norms, which confirmed the findings of a prior study in a Bangladeshi cohort.[26] Furthermore, measurements of the Beta angle were similar to the Caucasian norms,[6] and measurements of the Yen angle were similar to the Indian norms.[15,29] There was no sexual dimorphism in the findings of the present study; all sagittal measurements were similar between men and women. Conversely, Alam et al.[25] reported marginally higher values for men in all measurements of Steiner's analysis, but the differences were not statistically significant. However, another study showed a significant difference in the measurements of Wits appraisal between Bangladeshi men and women.[26] Overall, the results of the present study support the hypothesis that each racial group has unique norms based on morphological and anthropological characteristics.[34]

Conclusions

To the best of our knowledge, this is the first assessment of the sagittal discrepancy of jaw relationships using 3D CT in a Bangladeshi cohort. Moreover, Bangladeshi men and women exhibited similar craniofacial morphology and no sexual dimorphism in any sagittal measurements. This study is clinically relevant because it allows dental professionals to assess morphologic components associated with these irregularities and to more carefully establish specific diagnoses and treatment plans for patients. Finally, this study demonstrated that the 3D digitization method was very accurate and sensitive in acquiring the data, and can be used in both clinical practice and research applications.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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ORCID iD

Mohammad Khursheed Alam https://orcid.org/0000-0001-7131-1752

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