Original Article

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DOI:
10.4103/jos.jos_56_23

An evaluation of cephalometric predictors of anterior open bite; An assessment of dental and skeletal parameters in an orthodontic population

Onyinye D. Umeh[1], Sylvester Chegwe[2] and Ifeoma L. Utomi[1]

Abstract

BACKGROUND: Anterior open bite (AOB) malocclusion is one of the highly challenging malocclusions. Cephalometric radiographs have been used for the diagnosis of occlusal anomalies in the vertical and anteroposterior directions. This study aims to compare skeletal and dental features in open and non-open bite subjects to identify factors that help predict and categorize open bites in a Nigerian population.

MATERIALS AND METHODS: Pretreatment cephalometric radiographs of 82 patients were recruited into this study. This study comprised 41 AOB patients and 41 (Class 1 malocclusion) patients (control group). The radiographs were obtained from the orthodontic unit, Department of Child Dental Health of the Lagos University Teaching Hospital, Idi-Araba Lagos. Cephalometric tracing and analysis of the obtained radiographs were used to identify and compare the skeletal and dental differences between the two groups.

RESULTS: The mean age of the participants was 20.47 ± 8.05 years. The patients consisted of 26 (31.7%) males and 56 (68.3%) females. There was a significant difference in the open bite depth indicator (ODI) of the open bite (*P* value < 0.001). There was a statistically significant increase in the vertical skeletal parameters – lower facial height (LFH), total facial height (TFH), posterior facial height (PFH), Frankfort-mandibular plane angle (FMA), mandibular-maxillary angle (MMA), and gonial angle in the AOB group compared to the control group. The vertical height of the dentoalveolar segments measured was all significantly increased in the open bite group compared to the control group.

CONCLUSION: The results suggest that the skeletal and dental vertical parameters, including ODI of the open bite subjects, varied compared with the non-open bite subjects in the Nigerian population studied and could be used to predict AOB tendency.

Keywords:

Anterior open bite, cephalometric assessment, dental, overbite depth indicator skeletal

[1]Department of Child Dental Health Faculty of Dental Sciences, College of Medicine University of Lagos, Lagos University Teaching Hospital, Lagos, Nigeria, [2]Resident Doctor, Department of Child Dental Health, Lagos University Teaching Hospital, Idi-Araba, Lagos, Nigeria

Address for correspondence:
Dr. Onyinye D. Umeh, Department of Child Dental Health, Faculty of Dental Sciences, College of Medicine, University of Lagos, Lagos University Teaching Hospital, Lagos, Nigeria.
E-mail: umehod@gmail.com

Submitted: 14-Apr-2023
Revised: 31-May-2023
Accepted: 08-Jan-2024
Published: 16-Feb-2024

Introduction

Anterior open bite (AOB) is defined as a lack of contact between anterior teeth.[1-3] It was also defined as the absence of coverage between the incisors (upper and lower) when the posterior teeth are in an occlusal position.[4] AOB is also described as a condition in which the upper incisor teeth crowns fail to overlap the incisal third of the lower incisor crowns when the mandible is brought into full occlusion and described as a vertical discrepancy.[5] This could be attributed to supra eruption of the posterior

How to cite this article: Umeh OD, Chegwe S, Utomi IL. An evaluation of cephalometric predictors of anterior open bite; An assessment of dental and skeletal parameters in an orthodontic population. J Orthodont Sci 2024;13:10.

teeth or infra eruption of the anterior teeth. Otuyemi and Noar[6] described AOB as a relationship that exists when there is no incisor contact and vertical overlap of lower incisors by the uppers. It may occur with underlying class 1, class 2, or class 3 skeletal patterns.

McNamara and Burdon[4] classified open bite into skeletal and dental. Dental open bite is localized to the anterior teeth and the surrounding soft and hard tissues without presenting any skeletal defect in cephalometric radiograph, whereas, skeletal open bite shows vertical disharmony in cephalometric radiographs. Worms *et al*.[7] classified open bite into:

- Simple open bite – From canine to canine, with 4 mm or more in centric relation.
- Compound open bite – From premolar to premolar.
- Infantile open bite – From molar to molar.

Open bite malocclusion is one of the highly challenging orthodontic problems.[8,9] It is difficult to treat to a satisfactory, stable result and also has a relapse tendency.[8] The prevalence of AOB malocclusion ranges from 1.5% to 11% and varies between ethnic groups and according to age and dentition.[9] Proffit *et al*.[10] recorded a prevalence of approximately 3.5% in patients from 8 to 17 years of age.[10] In Nigerian studies, a prevalence ranging from 2.8 to 10.2% has been reported among different ages and ethnic groups,[11-15] with a lack of radiographic assessment of subjects with open bite. Therefore, understanding the etiology and proper diagnosis to aid in treatment planning.

Cephalometric radiographs have been used to diagnose orthodontic problems in vertical and anteroposterior directions. The use of cephalometric radiographs in clinical practice of orthodontics is well established. Using different cephalometric analysis methods, different authors have shown findings and measurements for open bite cases.[16-18]

The etiology of AOB is multifactorial but primarily differentiated into genetic and environmental causes, which include habits, tongue, airway obstruction, neuromuscular deficiency, trauma, rheumatoid disease, posture, and posterior discrepancy.[19]

Several studies have described the skeletal and dental characteristics of AOB and discussed the various etiological factors that play a role in producing open bite.[19-21] A study by Beane *et al*.[8] among black American adolescents and adults reported that subjects with open bite subjects differed in the extent of the vertical development pattern in the anterior face and mandibular rotation, with a protrusive dentoalveolar inclination as a significant component of the open bite malocclusion when compared to the control group. Daer and Abuaffan[22] similarly observed that the Yemeni open bite adults had different skeletal and dentoalveolar cephalometric measurements when compared to the average population.

This study aims to evaluate the dental and skeletal parameters of subjects with AOB malocclusion and compare them with subjects without AOB malocclusion in a Nigerian population. The findings of this study will help categorize open bite in a Nigerian population and guide the orthodontist in treatment planning when managing patients from this region.

Materials and Methods

This study was a retrospective cross-sectional study. Ethical approval was obtained from the Health Research Ethics Committee of the Lagos University Teaching Hospital Lagos before the commencement of this study (ADM/DCST/HREC/APP/3205).

The study population comprised patients with AOB and Class I malocclusion who attended the Lagos University Teaching Hospital Orthodontic unit between 2017 and 2022. Pretreatment lateral cephalometric radiographs of 82 patients were recruited into this study, consisting of 41 AOB patients and 41 normal (class I occlusion) patients with normal overbite and overjet with minimal intra-arch malocclusion (control group). The radiographs were obtained from the Orthodontic unit, Department of Child Dental Health of the Lagos University Teaching Hospital, Idi-Araba Lagos. The lateral cephalometric radiographs were traced on matte-finished acetate paper in a dark room. Illumination was provided using a fluorescent viewing box. All tracings were carried out by a single investigator (SE) identifying certain anatomic landmarks. From these tracings, points, planes, and angles were measured. The landmarks corresponded to those defined by Beane *et al*.[8] A total of 19 dental and skeletal cephalometric parameters were assessed. They included the following;

- Skeletal Anteroposterior
- Sella-Nasion-A point Angle (SNA)
- Sella-Nasion-B point Angle (SNB)
- A point-Nasion-B point Angle (ANB)
- Dental Anteroposterior
- Maxillary central incisor to Frankfort plane (U1 to FP)
- Mandibular central incisor to mandibular plane Angle (L1-MP)
- Inter-incisal Angle (U1 to L1)
- Skeletal Vertical
- Frankfort-mandibular plane Angle (FMA)
- Maxillary-mandibular plane (MMA)
- Lower anterior facial height (LFH)
- Total anterior facial height (TFH)
- Posterior facial height (PFH)

- Gonial Angle (Ar-Go-Me)
- ABpl-MP AB plane to mandibular plane (Angle)
- FH-PP Frankfort plane to maxillary (palatal) plane Angle
- ODI Overbite depth indicator (ABpl-MP minus FH-PP)
- Dental Vertical
- Maxillary incisor tip to the maxillary (palatal) plane (distance) (U1-PP)
- Maxillary molar cusp to maxillary (palatal) plane (distance) (U6-PP)
- Mandibular incisor tip to mandibular plane (distance) (L1-MP)
- Mandibular molar cusps to mandibular plane (distance) (L6-MP)
- Kim's overbite depth indicator (ODI) (22), which is claimed to be a reasonably good indicator of open bite tendency, was calculated from the AB plane to mandibular plane Angle (ABpl-MP) and the Frankfort plane to maxillary (palatal) plane (FH-PP) variables.
- The angle formed by the Frankfort plane to the maxillary (palatal) plane (FH-PP) Angle was either added or subtracted from the AB plane to the mandibular plane Angle (ABpl-MP)
- Added if the palate is tipped down in front
- Subtracted if the palate is tipped down posteriorly.

Statistical analysis

All statistical analysis was performed with the Statistical Package for Social Sciences (SPSS) program (version 25). For each variable, the mean and standard deviation was calculated. A *P* value of less than 0.05 was considered significant. For each measurement, an analysis of covariance was used to assess whether the mean values of the open bite and non-open bite groups differed. Age was entered in the analysis as a covariate, and the cephalometric means of the two groups were compared at the mean overall age. Without this adjustment, we determined whether a significant difference between the means was solely due to the effect of age.

Reliability of the measurement

The intraexaminer reliability test was carried out for error testing. Ten cephalometric radiographs - Five from each group - were randomly selected and retraced in 1-week intervals by the same investigator. The first and second measurements were compared using intraclass correlation coefficients (ICC) and Dahlberg errors to examine systematic and random errors, respectively, in the measurements.

- Dahlberg error was calculated using the formula below;
- Dahlberg formula, $D = \sqrt{\sum^{N}_{i=1} ((d_i)^2/2N)}$
- Where;
- di = the difference between the first and second measure
- N = sample size, which was re-measured.
- The results are shown in the table below [Table 1]

Results

A total of 82 patients were recruited into this study, consisting of 41 AOB patients and normal (class 1 occlusion) patients (control group) each. The age range of participants was 8 to 45, with a mean age of 20.47 ± 8.05 years.[Figure 1]The patients consist of 26 (31.7%) males and 56 (68.3%) females, with a ratio of 1:2.2 [Table 2] [Figure 2].

From the evaluation of the skeletal anterior-posterior measures, using the cephalometric land marks [Figure 3], the SNA and ANB values were observed to be slightly higher in the non-open bite group compared to the open bite group. The SNB value was, however, slightly higher in the open bite group compared to the non-open bite group. None of the measurements showed any statistically significant differences. (*P*-value < 0.05) [Table 3].

An assessment of the skeletal vertical cephalometric measurements showed statistically significant variations between subjects with AOB and the control

Table 1: Error of measurements between anterior open bite group and class 1 occlusion patients using Dahlberg formula and intraclass correlation coefficient

Cephalometric measurements	Intraclass correlation		Dahlberg error	
	AOB	Class 1 occlusion	AOB	Class 1 occlusion
SNA	0.55	0.71	3.53	1.55
SNB	0.44	0.84	3.88	1.05
ANB	−0.09	0.85	2.30	0.84
UI TO FP	0.82	0.96	3.19	2.12
L1 TO MP	0.78	0.97	3.67	2.12
U1 TO L1	−0.38	0.99	6.91	1.55
FMA	0.94	0.60	0.79	2.79
MMA	0.48	0.95	4.31	1.27
LFH	0.93	0.62	2.55	1.22
TFH	0.84	0.20	6.76	3.87
PFH	0.96	0.22	2.65	4.32
GONIAL ANGLE	0.86	0.37	3.16	17.17
AB-MP	0.09	0.95	4.96	1.14
FH-PP	0.66	0.09	1.98	1.61
ODI	0.64	0.13	5.83	6.86
U1 TO PP	0.91	0.02	1.23	12.59
U6 TO PP	0.74	0.01	2.15	12.16
L1 TO MP	0.99	0.08	1.05	2.12
L6 TO MP	0.95	0.82	1.90	0.32

SNA=Sella-Nasion-A point (Angle), NB=Sella-Nasion-B point (Angle), ANB=A point-Nasion-B point (Angle), U1-L1=inter-incisal angle, U1-FP=upper incisor to Frankfort plane, L1-MP=lower incisor to the mandibular plane, LFH=lower anterior facial height, TFH=total anterior facial height, PFH=posterior facial height, AB-MP=AB plane to mandibular plane, FH-PP=Frankfort plane to maxillary plane angle, ODI=overbite depth indicator, FMA=Frankfort-mandibular plane angle, MMA=maxillary-mandibular plane angle

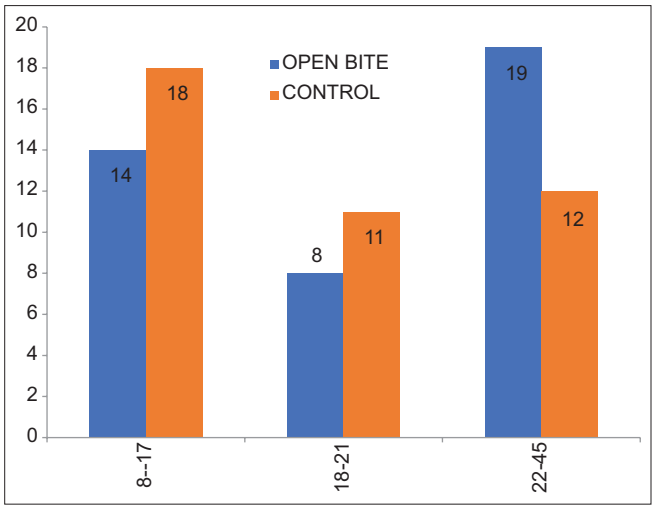

Figure 1: Age distribution of patients

Table 2: Age and gender distribution of patients

Variable	Frequency (*n*=82)	Percentage
Age		
8–17 (children/adolescents)	32	39.0
18–21 (young adults)	19	23.2
22–45 (mature adults)	31	37.8
Mean age (Mean±SD)	20.47±8.05	
Gender		
Males	26	31.7
Females	56	68.3

SD=Standard deviation

group in all nine vertical parameters measured except the FH-PP [Table 4]. The LFH, TFH, PFH, gonial angle, FMA, and MMA were significantly increased/higher in the open bite group when compared to the control group ($P < 0.05$). On the other hand, the AB plane to mandibular plane (AB-MP) and ODI values were significantly higher in the control (class 1 occlusion) group compared to the open bite group ($P < 0.05$). The mean AB-MP measurements were 63.62 ± 5.01 and 67.88 ± 6.08 in the open bite and control groups, respectively, with a P value of <0.001. There was a significant difference in the ODI of the open bite (62.18 ± 7.11) and control (69.00 ± 9.39) group with P value <0.001. There was no significant difference in the Frankfort plane to the palatal plane (FH-PP) ($P > 0.05$) [Table 4].

In examining the anteroposterior position and angulation of the upper and lower dentitions, the inter-incisal angle (U1-L1) was significantly lower in the open bite group compared to the control group (P value <0.001). The upper incisor to Frankfort plane (U1-FP) and the lower incisor to the mandibular plane (L1-MP) values were higher in the open bite group compared to the control group; however, although statistically insignificant (0.065, 0.215) [Table 5].

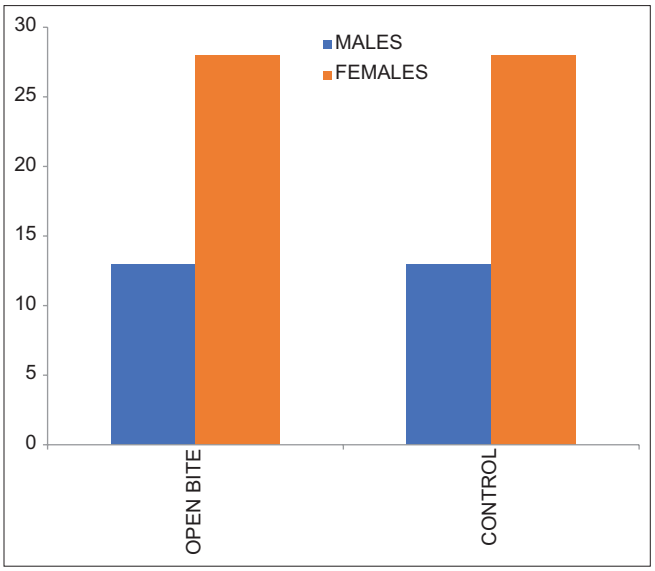

Figure 2: Gender distribution of participants

An evaluation of the vertical height of the dentoalveolar segments showed a statistically significant increase in the values observed in the open bite group compared to the control group ($P < 0.001$) [Table 6].

Discussion

This study aimed to compare the skeletal and dental features of AOB cases with the non-open bite cases in an African population. AOB is one of the highly challenging malocclusions to manage. It is difficult to treat to a satisfactory, stable result and also has a relapse tendency. These challenges may be attributed to multiple etiological factors as well as variations in dental and skeletal profiles with different AOB cases.

AOB is a malocclusion that has been reported with a higher prevalence in the Black/African population compared to other populations.[9-15] demonstrating an increased preponderance in the younger population.[11,13] The higher prevalence of open bite malocclusion in the younger age group was observed in this study, although statistically insignificant. This finding, in part, may be attributed to the higher prevalence of oral habits in children, which is a contributory factor in the etiology of open bite.[5,8]

The SNA and SNB values observed for the normal/control group in this study were 86.06^0 ± 3.9 and 81.49^0 ± 4.03 respectively. This is similar to values obtained from previous studies in Nigerian populations,[23,24] but contrary to the findings of Utomi[25], who reported relatively lower values. Variable ethnic groups within this population may be responsible for the variations among different researchers. In this study, all the skeletal anterior-posterior measures were higher in the

Table 3: Descriptive statistics for skeletal anterior-posterior cephalometric measurements

	P (age)	Before adjusting for age		After adjusting for age		*P* (group)
		Mean±SD		At mean age		
		Open bite	Control	Open bite	Control	
SNA	0.481	85.80°±4.64	86.06°±3.90	85.75°	86.11	0.707
SNB	0.071	82.21°±4.74	81.49°±4.03	82.07°	81.63	0.650
ANB	0.212	4.16°±2.76	4.57°±2.26	4.21°	4.52	0.591

SNA=Sella-Nasion-A point (Angle), NB=Sella-Nasion-B point (Angle), ANB=A point-Nasion-B point (Angle)

Table 4: Skeletal vertical cephalometric measurements

	P (age)	Before adjusting for age		After adjusting for age		*P* (group)
		Mean±SD		At mean age		
		Open bite	Control	Open bite	Control	
LFH (mm)	0.035	75.61±9.63	61.49±11.64	75.22	61.88	<0.001*
TFH (mm)	0.018	127.83±14.77	106.98±19.81	127.11	107.70	<0.001*
PFH (mm)	0.002	78.12±12.25	66.00±11.46	77.48	66.64	<0.001*
Gonial angle (°)	0.107	131.73±6.19	125.66±11.17	131.99	125.40	0.001*
AB-MP	0.598	63.62±5.01	67.88±6.08	63.67	67.83	0.001*
FH-PP	0.937	5.76±2.95	5.07±2.44	5.76	5.07	0.261
ODI	0.648	62.18±7.11	69.00±9.39	62.11	69.07	<0.001*
FMA (°)	0.619	30.88±4.97	28.27±5.54	30.92	28.22	0.025*
MMA (°)	0.135	33.85±5.59	31.51±5.35	34.00	31.37	0.033*

LFH=lower anterior facial height, TFH=total anterior facial height, PFH=posterior facial height, AB-MP=AB plane to mandibular plane, FH-PP=Frankfort plane to maxillary plane angle, ODI=overbite depth indicator, FMA=Frankfort-mandibular plane angle, MMA=maxillary-mandibular plane angle

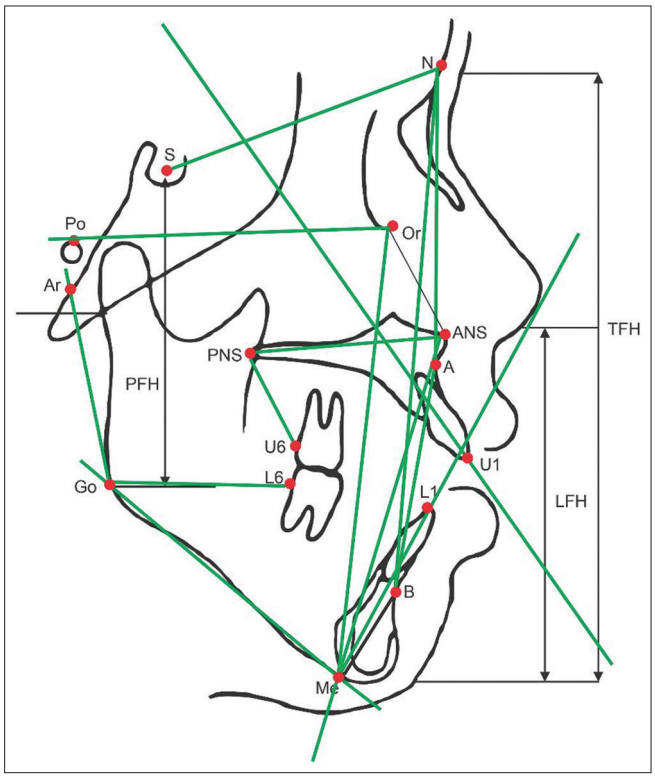

Figure 3: Cephalometric lines and angles

open bite group compared to the non-open bite group, although statistically insignificant (*P* value > 0.05). These values are comparable to previous reports among Caucasians[19,20] and similar to a study carried out in a black population.[8] This is not surprising as AOB is a vertical discrepancy and unlikely to alter horizontal variables on the cephalometric radiograph. This slight increase in these skeletal anteroposterior parameters may be suggestive of a tendency towards bimaxillary prognathism in the open bite population.

AOB is a malocclusion in the vertical dimension; hence, it was relatable that an evaluation of the vertical cephalometric measurements in this study showed a significant increase in the LFH, TFH, PFH, FMA, MMA, and gonial angle in the AOB group compared to the control group. These significantly higher values observed in the AOB population are in tandem with previous reports.[8,19,20] This observation shows a pointer to the significant effect of the skeletal components as a major cause of AOB in the Nigerian population.

The ODI of Kim[22] is considered a good indicator of open bite tendency ODI. This value is obtained by the measurement of two facial angles: the ABpl-MP and PP to FH. The incidence of open bite increases with a value below the mean of 75°[22] and has been proven to be the most reliable cephalometric assessment of open bite tendency.[26,27]

In our current study, we observed an ODI value of the open bite of 62.18 ± 7.11 and the control group of 69.00 ± 9.39. The results of this study compare with a previous study among Nigerians aged 18–25 years with values of 63.13 ± 6.71 and 66.85 ± 4.5[28] in the AOB and control groups, respectively. Another black population study also revealed a lower ODI study in

Table 5: Dental anterior-posterior cephalometric measurements

	P (age)	Before adjusting for age		After adjusting for age		*P* (group)
		Mean±SD		At mean age		
		Open bite	Control	Open bite	Control	
U1 to FP (°)	0.883	127.79±7.94	124.40±8.37	127.81	124.38	0.065
L1 to MP (°)	0.393	102.99±7.13	100.76±7.25	102.88	100.87	0.215
U1 to L1 (°)	0.681	97.02±9.85	106.85±10.44	97.10	106.78	<0.001

U1-L1=inter-incisal angle, U1-FP=upper incisor to Frankfort plane, L1-MP=lower incisor to the mandibular plane

Table 6: Dental vertical cephalometric measurements

	P (age)	Before adjusting for age		After adjusting for age		*P* (group)
		Mean±SD		At mean age		
		Open bite	Control	Open bite	Control	
U1-PP (mm)	0.244	41.17±9.12	33.46±5.83	41.01	33.62	<0.001
U6-PP (mm)	<0.001	26.73±4.13	21.78±4.85	26.45	22.06	<0.001
L1-MP (mm)	0.004	49.71±7.38	42.20±7.51	49.34	42.57	<0.001
L6-MP (mm)	0.003	36.49±6.40	29.59±5.35	36.18	29.89	<0.001

U1-PP=maxillary incisor tip to the maxillary plane U6-PP=maxillary molar cusp to maxillary plane, L1-MP=mandibular incisor tip to mandibular plane, L6-MP=mandibular molar cusps to mandibular plane

the AOB cases compared to the control group, although slightly higher than that reported by the current study, thereby validating the efficacy of the ODI in predicting a tendency towards AOB. The slight difference seen when compared to Nigerian studies may be attributed to race, as the study was carried out in African Americans.

One finding, however, which was consistent with the studies among the black population is the relatively lower ODI reported both between the open bite and control subjects when compared with the 75 degrees baseline of Kim.[22] This may be suggestive of open bite tendency in the black race, as reported by a previous study.[19] The vertical height of the dentoalveolar segments measured were all significantly increased, especially the posterior teeth in the open bite group compared to the control group in this study, as previously reported.[8] The significantly reduced inter-incisal angle observed in the AOB group suggested a tendency towards bimaxillary proclination in the AOB subjects. These dental parameters may, therefore, be pointers towards AOB tendencies in this population.

Based on the above findings, the clinician must consider the following in the management of the African/Nigerian population: firstly, including posterior teeth in treatment mechanics may result in a more satisfactory treatment outcome. Treatment that incorporates modalities requiring posterior teeth intrusion may achieve better treatment success. Secondly, extraction treatment may be desirable due to the bimaxillary proclination tendency of Nigerian patients with AOB. The clinician must discuss the role of surgery in the management of these patients, as the etiology of the AOB has proven to be of both dental and skeletal origin. The retrospective nature of the study, as well as the inability of this study to capture all ethnicities in the Nigerian Population may be considered the study limitations. A multi-center study at different locations, including different ethnic groups is advised to evaluate if similar or varied results would be obtained.

Conclusion

The study confirms the significant role of both dental and skeletal factors in the AOB observed in the study population compared to the control population.

The ODI was significantly lower in the AOB cases compared to the control group. There were also significantly higher values of TFH, LFH, FMA, MMA, and gonial angle in AOB compared with the control group.

The ODI, as well as the aforementioned skeletal parameters, may, therefore, be used as skeletal predictors of AOB.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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