Pharyngeal Dimensions in Skeletal Class I, II, and III Orthodontic Patients in a Nigerian Population

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ABSTRACT

Background: Routine lateral cephalometric radiographs can determine upper and lower pharyngeal airway constriction or patency depending on the dentofacial skeletal discrepancy. Appropriate orthodontic treatment that would maintain or improve the airway patency can be considered if the width of the airway in the various skeletal classes is determined. **Aim:** The aim of this study was to evaluate the upper and lower pharyngeal widths in skeletal Class I, II, and III untreated orthodontic patients in Benin City, Nigeria. **Materials and Methods:** In this study, 188 lateral cephalometric radiographs comprising three groups based on the ANB angle: Class I (ANB 2–4°), Class II (ANB >4), and Class III (ANB < 2) were analyzed using the method described by McNamara. The vertical facial pattern (the Sella–Nasion-GoGn angle) and palatal length were also determined. The differences between groups and correlations between variables were determined with the Students *t*-test and the Spearman correlation coefficient, respectively. **Results:** The mean upper and lower pharyngeal width for skeletal Classes I were 10.56 ± 3.67 mm and 11.14 ± 3.79 mm, respectively. Skeletal Class II had the narrowest upper airway width, whereas skeletal Class III had the narrowest lower airway widths, respectively. The palatal length was 9.04 mm in males and 8.6 mm in females, and there was a highly statistically significant difference $P < 0.05$ between hyperdivergent facial pattern and the upper pharyngeal width. There was a significant difference between skeletal pattern II and the upper pharyngeal width. **Conclusion:** Pharyngeal dimensions should be taken into consideration when managing patients with skeletal patterns II and III and the hyperdivergent facial patterns.

Key words: Cephalometry; pharyngeal dimensions; skeletal pattern

Introduction

The lateral cephalometric radiograph is used routinely for orthodontic diagnosis and is useful in determining skeletal discrepancies. Narrowing or reduction of the nasopharyngeal airway is common among patients with craniofacial disorders which may include a short cranial base, reduction in the cranial base angle, bimaxillary retrusion, and retrognathic mandibles.[1] The dimensions of the pharynx for different ethnic groups and countries have been studied, and these are required for effective treatment planning.[2-4] Studies by McNamara[2] demonstrated a normal width of the upper pharyngeal airway space in Americans to be 15–20 mm and 11–14 mm for the lower pharyngeal airway space. A width of 2 mm or less in the upper pharynx may suggest airway impairment.[2,4] While smaller values for the lower pharynx are not important, larger values indicate a possible anterior posturing of the tongue either as a result of posture or tonsillar enlargement.[2,3] This present study was undertaken in an attempt to investigate the dimensions of the pharynx in individuals with the three different skeletal patterns in Benin City.

Maxillomandibular disharmony has been found to exist between an anterior maxillary vertical excess (long face

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growth pattern), oral breathing habits, tongue posture, and an open mouth.[1,3] Other oral habits have been found to cause deviations in the skeletal pattern which include constriction of the maxilla resulting in a tight nasal inlet and a reduction in the airway diameter.[1-4] The baseline upper and lower airway values must be considered during the initial pretreatment planning to determine the type of treatment modality based on the skeletal pattern.[1-4] However, in Benin City, there appear to be no studies on the baseline upper and lower airway widths in patients with various skeletal patterns, hence the need for this study.

The evaluation of the widths of the upper and lower pharynx in the various types of malocclusion is a routine procedure in orthodontic diagnosis and treatment planning.[1-3] It is also important in order to determine and plan orthodontic and possibly orthognathic treatment strategies in patients with narrow upper and lower pharyngeal widths.[3,5] The study of the upper airway diameter utilizing cephalometric evaluation has recently become important in determining potential patients at risk for chronic obstructed nasal breathing and obstructive sleep apnea.[3,5] While many studies have found that skeletal Classes II and III malocclusions have been implicated in narrower and larger upper and lower pharyngeal widths, respectively,[6,7] others have identified other factors to include a longer soft palate, increased lower facial height, and maxilla-mandibular plane angle, and a more inferior position of the hyoid bone to have an effect on the dimensions of the airway.[3,4,8,9] Cephalometric studies have been previously carried out before orthodontic treatment in our environment[10-13] with apparently few studies[14] evaluating the pharyngeal width of the nasopharyngeal airway for individuals with different skeletal patterns. Poor treatment planning in individuals with a narrow airway would further complicate and constrict the airway with possible complications.[3] Proper treatment planning would however enhance the use of adequate and effective procedures to enhance the width of the airway by either advancement of the mandible alone or bimaxillary advancement.[3-5] Knowledge of the normal widths of the upper and lower pharynx would be beneficial, so that a baseline value for Edo State would be obtained.

Treatment modalities appropriate for the specific problem would be incorporated in the initial treatment plan if normal values of the airway dimensions for our environment seen in skeletal Class I are compared with abnormal skeletal patterns seen in skeletal patterns II and III. Moreover, the vertical facial pattern can be compared with width of the airway and the three skeletal classes.

A functional width of the upper and lower airway may be maintained or corrected using either orthodontic appliances or a combined multidisciplinary approach with orthognathic surgery if a normal baseline value is evaluated prior to the commencement of treatment.

The aim of this study therefore was to evaluate the pharyngeal dimensions in skeletal Class I, II, and III orthodontic patients in Benin City, Nigeria.

Materials and Methods

This cross-sectional analytical study was carried out on 188 pretreatment standardized digital cephalometric radiographs of consecutive first time orthodontic patients of the University of Benin Teaching Hospital after obtaining clearance from the ethical committee of the hospital. Sample size was determined using data obtained from a previous Nigerian study[10] resulting in a total of 188 participants and a power of >90. This number was obtained after carefully evaluating 265 radiographs over a 5 year period (2009–2013) of all first time patients who met the inclusion criteria and selecting those with the clearest resolutions. Only radiographs with the clearest detail were analyzed.

Patients with congenital anomalies, medical conditions, and a previous history of orthodontic treatment or illnesses were excluded from the study. Children below the age of 7 years were also excluded from the study. All the patients' radiographs were taken by the same radiographic technician in a standardized manner using a digital cephalometric machine (Planmeca Proline XC with Dima × 3 X-ray, 2006 model) set at × 1.25 magnification as recommended by the manufacturer. The images generated were stored directly in the computer database created using the manufacturer's software (Dimaxis Pro version 4.1.4; Planmeca, Helsinki, Finland). Conventional measurements were taken using hardcopy printouts of the digital radiographs. Although a previous study found that slight enlargement may occur when printing hard copies of digital cephalograms, the size difference is minimal and regarded as clinically acceptable.[15,16]

The study group was divided into three based on the skeletal pattern using cephalometric analysis and the measurement of the ANB angle (Point A to nasion to point B), which represents the anteroposterior jaw relationship or the skeletal pattern.

Class I = 2–4°

Class II = >5°

Class III = <1°

Measurement of skeletal and dental problems

Sella–Nasion-A (SNA), Sella–Nasion-B (SNB) and interincisal angle were assessed using the Steiner analysis.[1]

1. SNA - SNA point (the innermost and concave part of the bony maxilla) to determine maxillary prognathism or retrognathism:
    - Nigerian values[10] of 82–89° were regarded as a normal maxilla
    - Values of <81° were regarded as a retrusive maxilla and >90° as maxillary prognathism[10]

2. SNB - SNB point (the innermost and concave part of the bony mandible) to determine mandibular prognathism or retrognathism:
   - Nigerian values of 79.5–85.9° were regarded as a normal mandible
   - Values of <79.4° were regarded as a retrusive mandible and >86° as mandibular prognathism.[10]
3. Interincisal angle - being the angle formed between the upper and lower incisors
   - Nigerian values of 108–116° were regarded as normal
   - Values of <107° were regarded as bimaxillary protrusion and >117° as bimaxillary retrusion.[10]

Measurement of vertical facial pattern

The SN-Go-Gn (SN to the Mandibular plane represented by Go-Gn) angle with the following values:[1]

- Normal = 33–37°
- Low angle (hypodivergent) = <32°
- High angle (hyperdivergent) = >38°.

Measurement of upper and lower airway

The upper and lower airways were measured directly from the cephalometric radiograph using a transparent plastic ruler according to the analysis of the airway by McNamara.[2]

- Upper airway width-measured from a point on the posterior outline of the soft palate to the closest point of the pharyngeal wall
- Lower airway width-measured from a point at the intersection of the posterior border of the tongue with the inferior border of the mandible to the closest point on the posterior pharyngeal wall. Where a double lower border of the mandible existed, the midpoint was taken as the lower border.

Measurement of palatal length

The soft palate as seen on the lateral cephalometric radiograph was outlined with a pencil. The length was identified as a point from the end of the posterior nasal spine to the most inferior point on the soft palate.

Statistical analysis

The data obtained was tested and analyzed with a Statistical Package for Social Sciences Software (SPSS) version 15.0 (Chicago, SPSS Inc.). Means and standard deviations for all variables were calculated. The Student's *t*-test was used to calculate the differences in the linear dimension of the upper and lower airway among the other variables. A one-way analysis of variance (ANOVA) was carried out to determine if there was any association between the upper and lower pharyngeal width, different skeletal patterns, palatal width, and the three vertical facial patterns. The differences between groups and correlations between variables were determined with the Kruskal–Wallis test and the Spearman correlation coefficient, respectively. The confidence level was set at 95% and probability values of $P < 0.05$ were regarded as significant. All tracings were done on 0.003' matte acetate paper under good lighting by the same investigator. Twenty randomly selected radiographs were retraced after a 2 week interval and the random error was calculated using Dahlberg's formula.[15] Method errors of the various cephalometric variables were <1.0 mm for linear measurements, and 1.2° for angular measurement. The systemic error of the two measurements was assessed with the Student's *t*-test with no significance between measurements.

Results

The total sample consisted of 81 (43.1%) male and 107 (56.9%) female. The mean upper pharyngeal width in males and female were 9.65 ± 3.45 mm and 9.92 ± 3.32 mm, respectively. The mean lower pharyngeal width in males was 11.29 ± 3.59 mm and 10.36 ± 3.06 mm in females. Skeletal Class I was seen in 63 (33.5%), II in 89 (47.3%), and III in 36 (19.1%). Skeletal Class II was highest in both male and female in the total sample in 43 (53.1%) and 46 (43%), respectively. Palatal length ranged from 4 mm to 19.5 mm ± 2.1. Table 1 shows the age distribution of upper and lower pharyngeal widths.

Figure 1 shows the cephalometric tracing demonstrating 6 linear and 4 angular measurements and the outline of the pharynx.

Table 2 shows the descriptive statistics for all the variables studied with a mean upper and lower pharyngeal width of 9.82 ± 3.37 mm and 10.76 ± 3.32 mm, respectively, and a mean SNA and SNB value of 85.6 and 81.6°, respectively.

Majority of participants had a normal maxilla (45.2%), whereas maxillary prognathism and retrognathism were seen in 26.6% and 28.2%, respectively. The mandible was normal in 47.9% and retrognathic in 30.3%. Mandibular prognathism was lowest with 21.8%. The interincisal angle, which determined bimaxillary protusion or retrusion, recorded a mean value of 110.9 ± 1.19°.

The vertical facial pattern type seen was normal in 47.9%, low angle in 21.8%, and high angle in 30.3%. High angle cases ranged from 38 to 55°, whereas low angle cases ranged

Table 1: Age distribution of upper and lower pharyngeal width

	Age (years)	*n*	Mean	SD	*P*
Upper pharyngeal width	7-15	90	9.117	3.347	0.017
	16-25	59	10.669	2.757	
	26-30	39	10.141	3.955	
Total	188				
Lower pharyngeal width	7-15	90	10.662	3.146	0.820
	16-25	59	10.975	3.433	
	26-30	39	10.756	3.594	
Total	188				

$P<0.05$; df=2. SD – Standard deviation

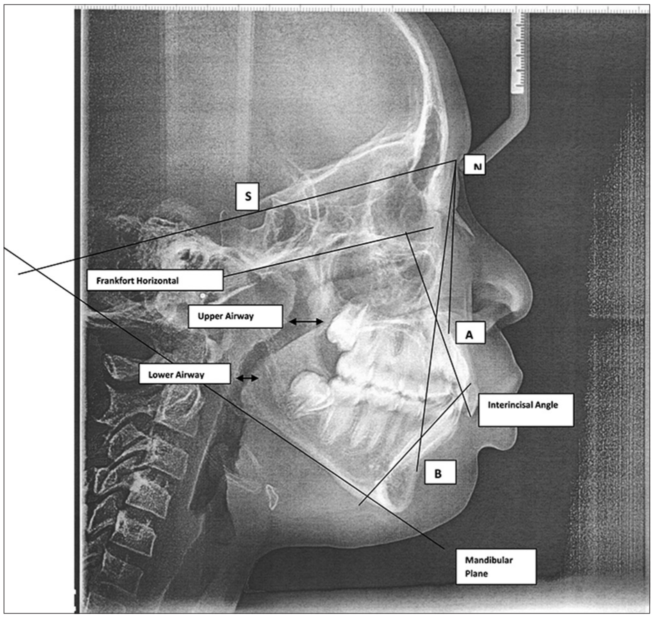

Figure 1: Cephalometric evaluation including upper and lower airway measurements

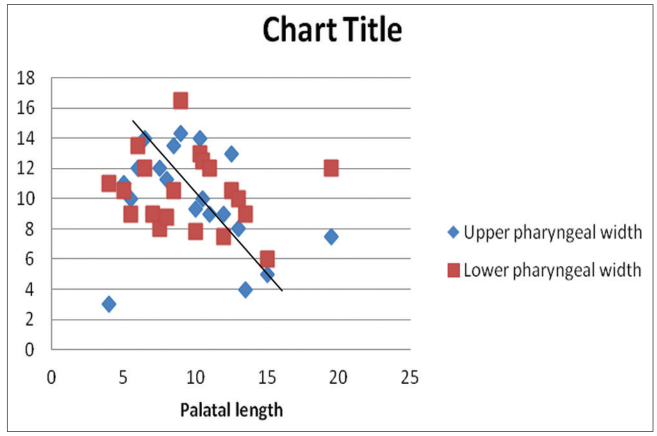

Figure 2: Scatter plot showing correlation with other variables and the palatal length as the dependent variable (r= −0.1, P < 0.05)

from 15 to 32°. A significant relationship; $P < 0.05$ was found between SNB and the facial pattern.

Table 3 shows a comparative evaluation between the upper and lower pharyngeal width and the three skeletal classes.

The one-way ANOVA between the skeletal class and SNA, SNB, and ANB was statistically significant ($P < 0.05$). The test of significance with the dependent variables of skeletal class and SNB, respectively, and the upper pharyngeal width demonstrated a significant relationship, $P < 0.05$.

There was a positive correlation between both upper and lower pharyngeal widths, $r = 0.30$, $P < 0.05$. The upper pharyngeal width correlated negatively with the mean palatal length ($r = -0.12$, $P < 0.05$). There was no significant relationship between the palatal length, lower pharyngeal width, and the inter incisal angle. Figure 2 shows a scatter plot demonstrating the strength and relationship of each variable.

Table 2: Cephalometric variables and values

Cephalometric variable	Total sample=188		Mean (n)	SE (n)	SD (n)
	Minimum	Maximum			
SNA	71.0	102.0	85.64	0.3883	5.32
SNB	68.0	99.0	81.66	0.3782	5.19
ANB	−11	13	3.95	0.259	3.56
Palatal length	4.0	19.5	8.71	0.1523	2.09
Skeletal class	1.0	3.0	1.86	0.0520	0.71
Facial pattern	15.0	55.0	35.16	0.5287	7.25
Upper pharyngeal width	1.0	19.0	9.82	0.2458	3.37
Lower pharyngeal width	1.0	26.0	10.76	0.2421	3.32
Interincisal angle	72.0	153.0	110.00	1.1972	16.42
UI to FH	71.0	137.0	116.03	1.0628	14.57
LI to MP	79.0	118.00	98.46	0.80073	10.98

UI – Upper incisor; FP – Frankfort horizontal, LI – Lower incisor; MP – Mandibular plane; SD – Standard deviation; SE – Standard error; SNB – Sella–Nasion-B; SNA – Sella–Nasion-A

Table 3: Skeletal class and upper pharyngeal width

Skeletal class	n	Upper pharyngeal width (mm)		Significant	Lower pharyngeal width (mm)		Significant
		Mean	SD		Mean	SD	
Class I	63	10.56	3.67	0.049*	11.14	3.79	0.543
Class II	89	9.22	2.99		10.60	2.79	
Class III	36	9.99	3.54		10.50	3.68	
Total	188	9.82	3.34		10.76	3.32	

*$P < 0.05$. SD – Standard deviation

Discussion

The results obtained from this study showed a mean upper and lower pharyngeal width of 10.56 ± 3.56 mm and 11.14 ± 3.79 mm, respectively, in Class I skeletal pattern. Previous studies by McNamara[1,2] showed that the (normal) width of the upper pharyngeal airway space in Americans to be 15–20 mm and 11–14 mm for the lower pharyngeal airway space in skeletal pattern I. Studies among Chinese[5] showed the mean upper and lower airway to be 11.77 ± 4.29 and 10.42 ± 3.46, respectively, whereas European studies obtained a mean upper and lower airway measurements of 12.9 mm and 12.25 mm, respectively, for skeletal pattern I also. The mean upper and lower airway in the American study[1,2] varies with the values in this study; however, the values from the Chinese[5] and European[17] population studied are close to the values of both upper and lower airway in this present study for skeletal pattern I basal bone relationship. This variation could be as a result of racial predisposition as studies have shown that Africans and Asians tend to have a reduced upper pharyngeal airway as a result of their predisposition to bimaxillary protrusion[5,10,14]

This study demonstrated a significantly smaller upper airway in the younger age groups with the 7–15-year-old recording 9.117 ± 3.35 mm. Coincidentally, the 16–25-year-old age group had the largest upper airway. It appears that the upper airway increases in size from 7 to 25-years of age and begins to reduce in its anteroposterior diameter from 26-years of age. However, the lower airway remained within the same width in the three age groups studied. When comparing the age distribution of the upper airway from other studies,[17,18] it appeared there was a differential growth pattern in the 6–18-year-old with a mean upper airway width of 8.92 ± 2.74 for the 6-year-olds and 16.55 ± 3.04 for the 18-year-old, respectively.[18] This is in agreement with this present study where the 16–18-year-old had the largest upper airway width and also with other studies which demonstrated that the width of the upper airway is dependent on growth of the child.[17,18]

Females in this study showed a slightly wider upper pharyngeal airway than males, whereas males tended to have a wider lower pharyngeal airway while this was in agreement with studies by Dobrowolska-Zarzycka *et al*.[17] It was also in contrast with other studies which showed that females tended to have a wider lower airway than males.[19] However, other studies[4,6,20] showed no gender difference between the upper and lower airways. These variations could be as a result of ethnicity as these other studies were carried out in Saudis,[4] Brazilian,[6] and Indian[20] children and this present study was carried out in Africans. This may indicate that race could be a factor in the upper and lower pharyngeal widths among gender.

In this study, Class II malocclusion demonstrated the narrowest mean airway value with 9.22 ± 3.0 mm. There was also a significant relationship in this study between Class II skeletal pattern and the upper pharyngeal width. Studies by Kirjavainen and Kirjavainen[18] found out that Class II division 1 malocclusion is associated with a narrower upper airway even without retrognathia. While their studies[18] showed an upper airway width in Class II untreated orthodontic patients ranging from 19.0 to 23.2 mm, which is much higher than the results obtained from this present study, their results could be as result of an increased tendency to bimaxillay proclination in Africans[11,14] and Asians.[5,8,9] Studies have shown those treatment modalities such as mandibular advancement and the use of head gear in treating Class II malocclusions results in an increase in the upper airway width.[3,5,18,19,21]

This study recorded a mean upper pharyngeal width of 9.99 ± 3.5 in Class III skeletal pattern but had no significant relationship with the upper and lower airway Skeletal Class III also showed the narrowest value in the lower pharynx. This is in contrast with studies by Eslamian *et al*.[19] and another study[17] which showed that Class III skeletal patterns had a larger upper airway. This could be as result of racial differences as the three studies are from different races

This study showed a mean value for bimaxillary proclination as 110.82 ± 1.76 in males and 109.38 ± 1.63 in females. The mean value for bimaxillary proclination in this present study is 110 ± 1.19. This is in contrast with another Nigerian study,[14] which gave a mean bimaxillary value of 118.44 ± 7.86. While the gender distinction was not stated, it appears that values may differ among ethnic groups as this study[14] was carried out in a different region from this present study.

This study showed a significant hyperdivergent facial pattern in relation with the upper airway. This is in agreement with other studies which showed significant changes in the upper airway in high angle cases[22,23] and in contrast with other studies,[9,20,24,25] where there was no difference in hyperdivergent facial patterns and the upper airway. Studies[19] also showed that vertical growth pattern patients had a narrower upper and lower airway when compared with normal patients.

While some studies showed no significant difference in palatal length among gender,[26] other studies showed a range of 7.2–8.3 mm but with an age range of 9–14-year.[19] This study however demonstrated a mean soft palatal length of 8.71 ± 2.1 mm, but there was no significant relationship between the mean palatal length and the upper and lower pharyngeal width for the population under consideration. Moreover, there was a gender disparity between the palatal lengths with males having a longer palate than females. This variation could be as a result of hereditary,[20,25,27] genetic,[27] or environmental influences.[19] While this present study was carried out in Classes I, II, and III, the other comparative studies were done in twins[25] and only in Class II untreated orthodontic patients.[19] The results of this study showed a significant correlation of the upper pharyngeal width with the mean palatal length. The correlation coefficient in this study ($r = -0.12$, $P = 0.04$) demonstrated a weak negative linear relationship between the palatal length and the upper pharyngeal width. This indicates that a slight increase in the length of the soft palate will result in a subsequent reduction in the upper pharyngeal width.

Conclusion

This study showed that the lateral cephalometric radiograph is valuable in determining the pharyngeal airway width. Moreover, the airway dimension in this study differs in the three skeletal classes with Class II having the narrowest upper airway and Class III the smallest lower pharyngeal airway. This study also showed that the upper airway is narrower in hyperdivergent (high angle) patients, and the length of the soft palate may reduce the upper airway width. It appears that racial, ethnic, and gender differences exist in Asians, Europeans, Americans, and Africans in the upper and lower airway width.

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Conflicts of interest

There are no conflicts of interest.

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