Airway Analysis in Skeletal Class I and Class II Subjects with Different Growth Patterns: A 2D Cephalometric Study

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Original Article

ABSTRACT

Objective: A two-dimensional cephalometric study was carried out to assess the airway among individuals with Class I and Class II skeletal base. Materials and Methods: Class II subjects were further categorized into horizontal and vertical growers and average growth patterns to check the possible relationship between the facial skeleton and pharyngeal airway. Lateral cephalograms of 150 subjects were obtained using standard protocol in natural head position (NHP). Nasopharyngeal and oropharyngeal linear, and angular and nasopharyngeal area measurements were obtained using standardized tracing technique. Analysis of variance (ANOVA), level of significance, and post hoc Turkey’s test were performed to assess the correlation between skeletal pattern of the individual and airway dimension. Gender discrimination was assessed using independent sample t test. Results: In linear measurements, significant differences were observed among upper pharynx (0.039), adenoid tissue 1 (0.036), and adenoid tissue 2 (0.01). In angular measurements, differences were observed with angle of nasopharynx (0.008). The nasopharyngeal area measurements were also associated with significant difference (0.038) with Class II vertical growers less than those with Class I average and Class II horizontal groups. Conclusion: Class II vertical growers had significantly reduced nasopharyngeal airways.

KEYWORDS: Cephalometrics, natural head position, pharyngeal airway

INTRODUCTION

The pharynx comprises nasopharynx and oropharynx. They carry out of the two important functions of stomatognathic system called respiration and deglutition efficiently and in unison.[1] The close relationship between the pharyngeal structures and the dentofacial complex pattern therefore attracts the orthodontist’s attention.[2,3]

Cephalometrics is an important diagnostic tool in orthodontics and helps for analyzing craniofacial complex for anatomic and spatial variations, thereby helping in diagnosis and treatment planning of the subject in question. Cephalometrics has been considered as the most widely used imaging and diagnostic modality in literature.[4]

There has been always a controversial debate between the airway obstruction and dentofacial developmental pattern. Watson et al.[5] studied relation between malocclusion and airway obstruction and concluded that no association existed between aforesaid

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parameters. Aronson[6] found positive correlation between craniofacial skeleton and airway adequacy carried out by rhinomanometric measurements. Hence, this study was undertaken to test whether there is any association between pharyngeal airway and type of malocclusion.

**Aims and objectives**

The aims of this study were to assess the airway dimensions in skeletal Class I and Class II individuals, and to evaluate the relationship between airway and growth pattern.

**Materials and Methods**

The sample consisted of 150 subjects with age group of 17–25 years.

Patients enrolled in the present investigation were categorized based on cephalometric measurements for skeletal base and growth pattern. For assessing the anteroposterior jaw relations, ANB angle[1] and Beta angle[7] were considered. On the basis of these parameters, the sample was categorized into skeletal Class I and Class II. For assessing the growth pattern, FMA and Go-Gn-SN were chosen and were applied for Class II sample to categorize into horizontal and vertical growers.[8] Each group was further subdivided into males and females.

The groups include the following:

1. Twenty-five female subjects with skeletal Class I with average growth pattern
2. Twenty-five male subjects with skeletal Class I with average growth pattern
3. Twenty-five female subjects with skeletal Class II with horizontal growth pattern
4. Twenty-five male subjects with skeletal Class II with horizontal growth pattern
5. Twenty-five female subjects with skeletal Class II with vertical growth pattern
6. Twenty-five male subjects with skeletal Class II with vertical growth pattern

The inclusion criteria of the study included normal healthy subjects without clinical signs and symptoms of pharyngeal pathology and no prior history of orthodontic treatment.

**Methods**

The study was explained to all the subjects and informed consent was obtained. Digital cephalograms were obtained using a standardized technique.

**Standardization for obtaining digital cephalogram**

All the lateral cephalograms were recorded in natural head position (NHP). A mirror was placed one and half feet away from the cephalostat and the subject’s head was secured in cephalostat (Orthophos XG5/DR5/CEPH from Sirona, The Dental Company, New York, USA) and was asked to look into his own eyes with lips relaxed. The subject was also asked to clench on the posterior teeth adopting the position they normally show during the day. A bead line was hung from the roof of the cephalostat. The exposure parameters of the lateral cephalogram included exposure time: 9.4s, voltage: 73 kV, and current: 15 mA.

Exposure is carried out following forceful expiration before next inspiration. The subjects were instructed not to move the tongue and head and not to swallow during exposure. All the cephalograms were exposed with same exposure parameters and using the same machine.

The tracings were carried out by single calibrated examiner. Nasopharyngeal linear ([UP], [LP], [AD1], and[AD2]) [Figures 1 and 2], angular (saddle angle, angle of nasopharynx and vertical angle of nasopharynx) [Figure 3], and areal measurements [Figure 4] were calculated. The area of the bony nasopharynx is a trapezoid formed by the following planes:

1. AA-PNS
2. Ba-N
3. Palatal plane
4. Pterygoid vertical

The trapezium is formed by superiorly by Ba-N plane; inferiorly by palatal plane extension; anteriorly by pterygoid vertical and posteriorly by

![Figure 1: Nasopharyngeal linear measurements](image)
Atlas Anterior line (AA). The area of the adenoid tissue contained within the trapezoid depicts the nasopharynx.\textsuperscript{[11]}

Formula for calculating the area of nasopharynx is as follows: \( \text{NP area} = d \left[ h - d \tan \Theta / 2 \right] \).

The cephalograms were also traced for oropharyngeal linear measurements (MPW, TPPW, and LPW) [Figure 5]. In total, 10% of the lateral cephalograms were retraced after 1 week to check for intra-examiner reliability.

All the analysis was performed using Statistical Package for the Social Sciences (SPSS) software program, version 14.0. Intergroup comparisons were performed using analysis of variance (ANOVA) test. If \( P \) value was significant, then a \textit{post hoc} Turkey’s test was performed to check which two groups were statistically different from each other. A value of \( P < 0.05 \) was set to be statistically significant.

\section*{RESULTS}

\textbf{Nasopharyngeal measurements}

In linear measurements, statistically significant differences were observed in the values of upper pharynx (UP), adenoid tissue 1 (AD1), and adenoid tissue 2 (AD2) with Class II vertical group less than those with Class I average group with \( P = 0.039, 0.036, \) and 0.01, respectively [Table 1].

In angular measurements, the significant differences were found in angle of nasopharynx and saddle angle with Class II group less than those with Class I average group with \( P = 0.008 \) and 0.0190, respectively [Table 2].

The areal measurements revealed vertical group values being less than those with Class I average group and Class II horizontal groups (\( P = 0.038 \)) [Table 3].

\textbf{Oropharyngeal measurements}

No statistically significant differences were observed in any of the parameters as tested by ANOVA [Table 4].

No gender differences were observed following independent \( t \) test [Tables 5–7].

\section*{DISCUSSION}

The higher frequency of nasopharyngeal obstruction in growing children and the association of it to the growth of craniofacial skeleton demands for an economical, easily assessable, simple tool to diagnose the airway obstruction. The adenoid size when assessed using lateral cephalograms was found to have clinically useful correlations particularly with respect to area measurements.\textsuperscript{[12,13]}

Lateral cephalograms of all the subjects were obtained in NHP with subjects standing in orthoposition.\textsuperscript{[14–16]} Cooke and Wei\textsuperscript{[17–19]} also stated that NHP reproducibility
was better with mirror method. The exposure was carried out at the end of expiration before next inspiration as this method has the added advantage of recording airway better because during quiet breathing airway resistance is greater during expiration than inspiration.\textsuperscript{[9,10]}

### Table 1: Definition of surface landmarks used in cephalometric analysis

| Landmark            | Abbreviation | Definition                                                                 |
|---------------------|--------------|----------------------------------------------------------------------------|
| Sella               | S            | The deepest point on the anterior curvature of the sella tursica           |
| So                  | So           | Midpoint of the sella basion line.                                        |
| Nasion              | N            | The intersection of the internasal and frontonasal sutures, in the midsagittal plane |
| Anterior nasal spine| ANS          | The tip of the bony anterior nasal spine at the inferior margin of the piriform aperture, in the midsagittal plane |
| Posterior nasal spine| PNS         | This is a constructed, radiographic, lateral cephalometric point, located at the intersection of the continuation of the anterior wall of the pterygopalatine fossa and the floor of the nose. |
| Subspinale          | Point A      | The deepest midline point on the premaxillae between the ANS and prosthion. |
| Supramentale        | Point B      | The most posterior point in the concavity between infradentale and pogonion. |
| Condylion           | Co           | The center of the condyle, found by tracing the head of the condyle and approximating its centre. |
| Porion              | Po           | The highest bony point on the upper margin of external auditory meatus.    |
| Orbitale            | Or           | The lowest point on the inferior bony margin of the orbit.                 |
| Gonion              | Go           | It is a constructed point at the junction of ramal plane and the mandibular plane. |
| Gnathion            | Gn           | It is the most antero-inferior point on the symphysis of the chin.         |
| Basion              | Ba           | The most posterior limit of the lowest point in the midline on the anterior margin of the foramen magnum. |
| Uvula               | U            | Tip of soft palate                                                         |
| Vallecula           | V            | The most posteroinferior point on the base of the tongue                   |
| Adenoid 1           | AD1          | Intersection of the line PNS-ba (basion) and the posterior nasopharyngeal wall |
| Adenoid 2           | AD2          | Intersection of the line PNS-midpoint of sella (so) and the posterior nasopharyngeal wall |
| C2                  | CV2P         | The most posterior point on the inferior margin of the outline of the body of the second cervical vertebra. |

### Table 2: Nasopharyngeal angular measurements

| S. no. | Parameter | Group          | Mean   | SD    | P Value | Post hoc test |
|--------|-----------|----------------|--------|-------|---------|---------------|
| 1      | BA-S-PNS  | Class I average (1) | 62.56  | 4.90  | 0.008   | 1 > 3        |
|        |           | Class II horizontal (2) | 60.92  | 4.0   |         |               |
|        |           | Class II vertical (3) | 59.72  | 4.55  |         |               |
| 2      | S-BA-PNS  | Class I average | 61.12  | 7.49  | 0.825   | –             |
|        |           | Class II horizontal | 61.70  | 3.90  |         |               |
|        |           | Class II vertical | 61.70  | 4.01  |         |               |
| 3      | SA        | Class I average (1) | 126.16 | 4.16  | 0.019   | 3 > 1        |
|        |           | Class II horizontal (2) | 127.82 | 4.97  |         |               |
|        |           | Class II vertical (3) | 128.64 | 4.12  |         |               |

SD = standard deviation

\( P \) value less than 0.05 is considered significant
Table 3: Nasopharyngeal area measurements

| S. no. | Parameter | Group                     | N  | Mean    | SD   | P Value | Post hoc test |
|-------|-----------|---------------------------|----|---------|------|---------|---------------|
| 1     | NP        | Class I average (1)       | 50 | 898.94  | 71.32| 0.038   | 1 > 3         |
|       |           | Class II horizontal (2)   | 50 | 888.15  | 162.67|         |               |
|       |           | Class II vertical (3)     | 50 | 838.68  | 122.31|         |               |

SD = standard deviation

P value less than 0.05 is considered significant

Table 4: Oropharyngeal linear measurements

| S. no. | Parameter | Group                     | N  | Mean    | SD   | P Value | Post hoc test |
|-------|-----------|---------------------------|----|---------|------|---------|---------------|
| 1     | MPW       | Class I average           | 50 | 15.48   | 4.15 | 0.064   | –             |
|       |           | Class II horizontal       | 50 | 13.96   | 3.81 |         |               |
|       |           | Class II vertical         | 50 | 14.02   | 2.8  |         |               |
| 2     | TPPW      | Class I average           | 50 | 12.62   | 2.83 | 0.168   | –             |
|       |           | Class II horizontal       | 50 | 11.98   | 3.58 |         |               |
|       |           | Class II vertical         | 50 | 13.18   | 3.00 |         |               |
| 3     | LPW       | Class I average           | 50 | 19.44   | 4.67 | 0.226   | –             |
|       |           | Class II horizontal       | 50 | 18.34   | 3.83 |         |               |
|       |           | Class II vertical         | 50 | 19.78   | 4.48 |         |               |

SD = standard deviation

Table 5: Gender differences in nasopharyngeal linear measurements

| Group            | Parameter  | Boys | SD     | Girls | SD     | P Value |
|------------------|------------|------|--------|-------|--------|---------|
| Class I average  | UP         | 17.00| 2.75   | 15.92 | 3.91   | 0.265   |
|                  | LP         | 12.68| 1.43   | 12.44 | 2.75   | 0.702   |
|                  | AD1        | 30.52| 6.14   | 29.00 | 5.01   | 0.342   |
|                  | AD2        | 26.24| 2.76   | 25.12 | 4.04   | 0.258   |
| Class II horizontal | UP     | 16.84| 3.87   | 15.48 | 2.89   | 0.166   |
|                  | LP         | 12.36| 2.74   | 11.76 | 3.21   | 0.48    |
|                  | AD1        | 28.84| 4.92   | 30.20 | 5.90   | 0.381   |
|                  | AD2        | 24.56| 2.02   | 23.40 | 3.07   | 0.121   |
| Class II vertical | UP       | 14.76| 2.88   | 15.00 | 2.94   | 0.772   |
|                  | LP         | 12.68| 2.28   | 12.16 | 2.72   | 0.468   |
|                  | AD1        | 30.56| 6.17   | 28.96 | 3.66   | 0.27    |
|                  | AD2        | 24.36| 3.21   | 23.92 | 2.80   | 0.608   |

UP = upper pharynx, LP = lower pharynx, AD1 = adenoid tissue 1, AD2 = adenoid tissue 2, SD = standard deviation

Table 6: Gender differences in nasopharyngeal angular and area measurements

| Group            | Parameter  | Boys | SD   | Girls | SD   | P value |
|------------------|------------|------|------|-------|------|---------|
| Class I average  | BA-S-PNS   | 61.24| 3.81 | 63.88 | 5.56 | 0.056   |
|                  | S-B-PNS    | 61.20| 9.51 | 61.04 | 4.89 | 0.941   |
|                  | SA         | 126.24| 3.89 | 126.08| 4.49 | 0.893   |
|                  | NP         | 958.11| 267.83| 873.24| 183.24| 0.197   |
| Class II horizontal | BA-S-PNS | 60.08| 3.46 | 61.76 | 4.39 | 0.14    |
|                  | S-B-PNS    | 62.64| 4.03 | 60.76 | 3.60 | 0.088   |
|                  | SA         | 127.56| 6.21 | 128.08| 3.43 | 0.716   |
|                  | NP         | 905.39| 151.68| 870.92| 174.34| 0.459   |
| Class II vertical | BA-S-PNS | 59.60| 4.17 | 59.84 | 4.98 | 0.854   |
|                  | S-B-PNS    | 61.96| 4.17 | 61.44 | 3.92 | 0.651   |
|                  | SA         | 128.12| 3.98 | 129.16| 4.27 | 0.378   |
|                  | NP         | 872.35| 135.48| 805.00| 99.13 | 0.051   |

SD = standard deviation
The use of lateral cephalometric radiographs to evaluate the airway is to an extent compromised as we are trying evaluate the complex three-dimensional (3D) structure of pharynx using 2D imaging.\(^{[18]}\) Malkoc et al.\(^{[20]}\) stated that “if certain technical requirements are fulfilled such as maintaining NHP, lateral cephalometry can provide useful information in estimating tongue and nasopharyngeal volume.” This observation was also made by Handelman and Osborne,\(^{[11]}\) who found that lateral cephalograms give a decent picture of pharyngeal airway size among children of all age groups.

Class II vertical growers had significantly narrower pharyngeal airways than Class I average and Class II horizontal growers, confirming previous results in the literature of de Freitas et al.\(^{[8]}\) and Dunn et al.\(^{[21]}\) Analyzing these results, inference can be drawn that upper airway width is influenced by craniofacial growth.\(^{[21]}\) The results of other linear nasopharyngeal measurements such as AD1 and AD2 also showed that individuals with Class II vertical growth pattern had significantly lesser values than Class I average and Class II horizontal growers [Table 1]. This was in accordance with the results of the studies of Martin et al.\(^{[14]}\) No statistically significant difference was observed in lower pharynx values among the three groups. With respect to the angle of nasopharynx, Class II group had significantly lower values than Class I average group. No statistically significant differences were observed in relation to depth of nasopharynx among the three groups [Table 2].

Table 7: Gender differences in oropharyngeal linear measurements

| Group            | Parameter | Boys |       | Girls |       | P Value |
|------------------|-----------|------|-------|-------|-------|---------|
|                  |           | Mean | SD    | Mean  | SD    |         |
| Class I average  | MPW       | 16.12| 3.72  | 14.84 | 4.52  | 0.134   |
|                  | TPPW      | 13.04| 2.47  | 12.20 | 3.15  | 0.3     |
|                  | LPW       | 20.4 | 5.47  | 18.48 | 3.56  | 0.148   |
| Class II horizontal | MPW  | 13.88| 3.32  | 14.04 | 4.32  | 0.884   |
|                  | TPPW      | 12.6 | 2.94  | 11.36 | 4.09  | 0.225   |
|                  | LPW       | 18.60| 3.62  | 18.08 | 4.08  | 0.636   |
| Class II vertical | MPW     | 14.52| 2.08  | 13.52 | 3.34  | 0.21    |
|                  | TPPW      | 13.72| 2.7   | 12.64 | 3.25  | 0.208   |
|                  | LPW       | 20.88| 4.68  | 18.68 | 4.07  | 0.082   |
|                  | LPW       | 20.88| 4.68  | 18.68 | 4.07  | 0.082   |

SD = standard deviation

The comparison of mean nasopharyngeal area values showed that subjects with Class II vertical growth pattern had significantly lower values compared to Class I average group [Table 3]. The comparison of mean oropharyngeal linear measurements showed that there were no statistically significant differences among the three groups [Table 4]. This is in accordance with the study of Ucar and Uysal,\(^{[22]}\) on orofacial dimensions in different growth patterns. Linder-Aronson and Leighton\(^{[23]}\) and Daraze et al.\(^{[24]}\) suggested that “oropharyngeal space appears to be larger than normal when the nasopharyngeal airway is smaller,” although they did not evaluate this correlation directly.

The sample was also analyzed for gender discrimination in pharyngeal airways. No statistically significant differences were observed in nasopharyngeal and oropharyngeal measurements among the three groups.
CONCLUSION
The following conclusions can be drawn from this study:
1. Class II vertical growers have less nasopharyngeal linear measurements (UP, AD1, and AD2) than Class I average growers.
2. Class II vertical growers have less nasopharyngeal angular measurements (angle of nasopharynx) than class I average growers.
3. Class II vertical growers have less nasopharyngeal area than Class I average growers and Class II horizontal growers.
4. No statistically significant differences were observed in oropharyngeal linear measurements among the three groups.
5. No gender differences were observed in any of the parameters among the three groups.

Short comings of the study
The sample has been restricted to Class I and Class II groups. The sample can be broadened to include Class III subjects also.

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Conflicts of interest
There are no conflicts of interest.

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