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# Comparison of Pharyngeal Dimensions and Volume in Skeletal Class I, Class II and Class III Subjects: A CBCT Study

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## ABSTRACT

**Objectives:** Aim of the study was to compare pharyngeal airway dimensions and volume in skeletal class I, class II and class III subjects using CBCT. **Methods:** the study sample consisted of 60 patients within the age range 18-35 yrs (34 females and 26 males) divided into 3 groups as group A- class I ($0^{\circ} \le$ ANB $\le 3^{\circ}$), groups B- class II(ANB >3) and group C- class III(ANB< 0) to evaluate how the change in skeletal pattern affects the OP and NP variables. The CBCT images were taken with Kodak 9500 cone beam 3D system. The Dolphin 3D program (Dolphin Imaging and Management Solutions) Chatsworth,Calif (version 11.4) was used to determine Oropharyngeal(OP) and Nasopharyngeal(NP) volumes and dimensions. Difference between groups was determined using Kruskal Wallis test and correlation between variables was determined using Pearson correlation coefficient. **Results:** The OP volume of class III patients was higher when compared to class I and class II whereas NP volume was higher in class I with statistically significant difference between groups. NP length was higher in class II when compared to class I and class III with statistically significant difference between groups. OP width and most constricted area were least in class II groups with statistically significant difference between class II and class III groups. **Conclusion:** Subjects with retruded position of mandible had an effect on OP volume. OP width and most constricted area varied significantly between class II and class III groups with smaller dimensions in class II.

**Key words:** Oropharyngeal volume, oropharyngeal width, nasopharyngeal volume, nasopharyngeal width, cone beam computed tomography, Dolphin imaging software.

## INTRODUCTION

Upper and lower pharyngeal airway has been an area of interest in orthodontics as the oropharyngeal and nasopharyngeal structures play an important role in growth and development of dentofacial complex. Airway dimensions and volume change with position of maxilla and mandible. The airway and mode of breathing are important during growth and development. Thus, it is imperative to normalize the form and function during the early ages of growth and development.

Pharyngeal constriction can cause various dentoskeletal changes due to mouth breathing such as excessive molar eruption, open bite, retrognathic mandible, retruded maxilla and increased lower facial height.[1,2] Constriction of airway can also lead to obstructive sleep apnoea(OSA). It is a condition of concern in day-to-day life as it can give rise to excessive daytime sleepiness due to lack of oxygen supply, snoring, cardiovascular diseases, cerebrovascular diseases, brain damage, high blood pressure, depression, morning headaches, poor memory, clouded thinking, irritability, sleep bruxism etc.

Precise diagnosis of the condition can therefore help the patients suffering with OSA to obtain ideal treatment. There are various methods by which pharyngeal airway dimensions can be measured which include conventional lateral cephalograms, computed tomography (CT), magnetic resonance imaging (MRI), endoscopy, optical coherence tomography etc. The latest method to assess airway volume and dimensions is through cone beam computed tomography which has various advantages such as low radiation dose, image accuracy when compared to grade multi-sliceCT because of sub-millimeter resolution and rapid scan time as all images are obtained in single rotation with isotropic volumetric data and reduced image artifact when compared to spiral CT and MRI .Thus CBCT proves to be a better diagnostic option when compared to other methods in accurate assessment of pharyngeal airway volume. The aim of the study was to compare the pharyngeal airway dimensions and volume in skeletal class I, class II and class III subjects using cone beam computed tomography.


**Fig 1**: Placement of seed points (yellow shaded) for volume measurement and the magenta shade indicates the area to be analyzed.

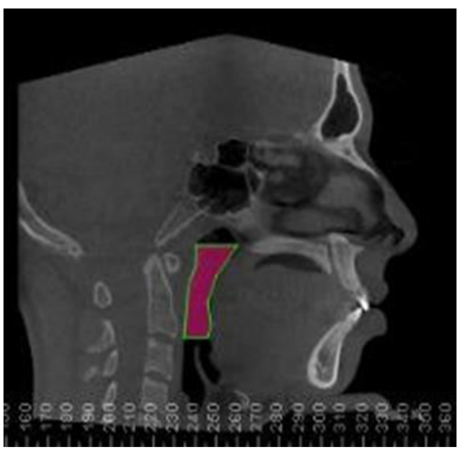

**Fig 2:**Oropharyngeal volume (OP) with superior limit as palatal plane (ANS-PNS) to posterior pharyngeal wall(ppw) and inferior limit as line parallel to palatal plane that passes from second cervical vertebrae as measured using Dolphin 3D Imaging software

## MATERIALS AND METHODS

Sample size determination was done by power analysis using 'n master software'; alpha error 5, power of 90% and sample mean 7375.3 and sample size was arrived as 20 per group for 3 groups using the formula $n = Z\alpha^2 \times s^2 \times d^2$

n- Sample size, z- normal deviation for 95%, α – significance error, s – Standard deviation, d – desired population.

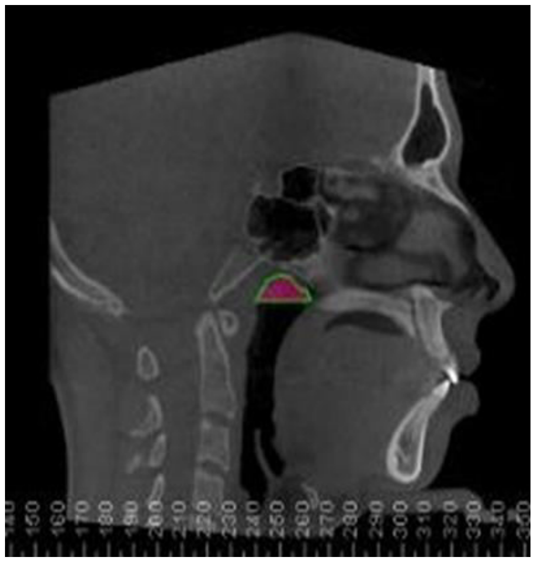

**Fig 3:** Nasopharyngeal volume (NP) with inferior limit as superior limit of oropharyngeal airway (PP) and superior limit as base of sphenoid bone as measured using Dolphin 3D imaging software.

The study was performed on 60 patients (34 females and 26 males) with skeletal class I, class II and class III patterns within age group of 18-35 years using CBCT. CBCT images were obtained after getting ethical clearance from Institutional Review Board. The CBCT images were taken using CS 9500 3D equipment – kodak (software version 1.10,volume size - 18×20cm, 9×15cm, power-16 amps,3 kVA, sensor technology – amorphous silicon flat panel, Kv-90, Ma-10, DICOM compatibility), with patient properly positioned at maximum intercuspation. All images were taken with resolution of 300µm ×300µm voxels. The patient's head was positioned with Frankfort plane (Po-Or) perpendicular to sagittal plane. These DICOM images were processed with CS 3D imaging software.

The inclusion criteria for the selection of cases were no history of previous orthodontic treatment, absence of facial asymmetry, all permanent teeth should be erupted except third molars, no functional mandibular deviation.

The following were the exclusion criteria: nasal obstruction, pathology of pharyngeal structures, snoring habit, sleep disordered respiration, patients who had undergone adenoidectomy or orthognathic surgeries.

CBCT images were taken for all the patients who met the inclusion criteria. The subjects were divided into three groups based on their ANB angle measurements as group A- class I ($0^\circ \leq$ ANB $\leq 3^\circ$ ), groups B- class II(ANB $>3^\circ$ ) and group C- class III(ANB$< 0^\circ$ ) to evaluate how the change in skeletal pattern affects the OP and NP variables.

The Dolphin 3D program (Dolphin imaging and management solutions, Chatsworth, Calif)(version11.4) was used to determine the Oropharyngeal (OP) and Nasopharyngeal (NP) volumes separately.

The Dolphin 3D program was used for volume, area and length and width measurements. The Dolphin 3D program allowed user to incorporate seed points to calculate the oropharyngeal and nasopharyngeal volumes respectively. The slice airway sensitivity was maintained at 25 which is software's default setting as it was the ideal sensitivity for expanding the seed point to adjacent empty areas in volume.

Table 1: Comparison of OP volume and area in the three skeletal patterns by Kruskalwallis test

| | OP VOLUME | | | OP AREA | | |
|---|---|---|---|---|---|---|
| Group | Mean ($\mu$)$mm^3$ | Std. Deviation ($\sigma$) $mm^3$ | Asy sig | Mean ($\mu$) $mm^2$ | Std. Deviation ($\sigma$) $mm^2$ | Asy Sig |
| A-CLASS I (20) | 10061.40 | 4735.186 | | 404.25 | 135.00 | |
| B-CLASS II(20) | 9987.20 | 4786.368 | 0.361 | 386.10 | 147.67 | 0.125 |
| C-CLASS III(20) | 17038.45 | 26332.539 | | 469.75 | 124.14 | |

*Placing seed points:*

It is a yellow shaded point which appears on the slice of the image (Fig 1). Seed points denote the densities that represent the airway and the target airway volume grow from these seed points. Click and drag the yellow point to an empty space that is part of patient's airway. The boundaries are drawn to restrict the airway analysis area and the seed points are placed inside all of boundaries. The magenta shade fills in the space where the seed point is placed and thus calculates the area and volume.

**Table-2: Comparison of OP length in the three skeletal groups by Kruskal Wallis test and OP width by ANOVA**

| | OP length | | | OP width | | | |
|---|---|---|---|---|---|---|---|
| Group | Mean ($\mu$) mm | Std. Deviation ($\sigma$) Mm | Asy sig | Mean ($\mu$) mm | Std. Deviation ($\sigma$) mm | F value | P value |
| CLASS I | 34.515 | 4.8589 | 0.834 | 21.880 | 2.4060 | 22.573 | 0.000 |
| CLASS II | 35.270 | 6.2119 | | 20.855 | 2.3048 | | |
| CLASS III | 34.825 | 4.5551 | | 25.600 | 2.3387 | | |

The following parameters were assessed from the CBCT images:

- Oropharyngeal (OP) volume
- Oropharyngeal (OP) length.
- Nasopharyngeal (NP) volume
- Nasopharyngeal (NP) length
- Oropharyngeal (OP) width
- Nasopharyngeal (NP) width
- Oropharyngeal (OP)area
- Nasopharyngeal (NP) area
- Most constricted (MinAx) area

*Statistical Analysis*

The collected numerical data was analysed with IBM.SPSS statistics software 23.0 Version. To describe about the data descriptive statistics frequency analysis, percentage analysis was used for categorical variables and the mean & S.D were used.The Shapiro Wilk's test for normality showed the data was skewed,hence in the multivariate analysis the Kruskal Wallis' test followed by Mann-Whitney U test was used. Chi-Square test was used to find the significance of categorical data. In both the above statistical tools, the probability value .05 was considered as a significant level. Spearman rank correlation was utilized to assess the relationship between variables.

## RESULTS

Results showed that in pharyngeal volume measurements oropharyngeal (OP) (Fig 2) volume (Table 1) was higher in class III group followed by class I & class II groups but the results were not satistically significant. In pharyngeal dimensions, OP length (Table 2) was increased in class II group but to no statistical significance.Oropharyngeal width was higher in class

| Table-3: Comparison of NP volume and area in three different skeletal patterns using KRUSKAL WALLIS TEST. | | | | | | |
|---|---|---|---|---|---|---|
| | NP volume | | | NP area | | |
| Group | Mean (μ) $mm^3$ | Std. Deviation (σ) $mm^3$ | Asy. sig | Mean (μ) $mm^3$ | Std. Deviation (σ) $mm^3$ | Asy. sig |
| ACLASS I | 7374.05 | 1883.982 | | 233.05 | 97.98 | |
| B CLASS II | 6090.85 | 2321.111 | 0.016 | 269.60 | 87.68 | 0.359 |
| C CLASS III | 5204.45 | 2225.494 | | 242.65 | 103.17 | |

III group to a significant level than the other two groups (Table 2). Nasopharyngeal (NP) (Fig 3) volume (Table 3) was higher to a statistically significant degree (0.016) in class I group followed by class II& class III groups. Similarly, NP length (Table 4) was higher in class II group to a significant degree than class III and class I groups. NP width (Table 4) was higher in class II group followed by class III & class I groups; the results were not statistically significant. There was no statistically significant difference between OP and NP area between the three groups (Table 1,3). Evaluation and comparison of the most constricted area of pharynx was extremely relevant to the study and when the same was compared it was found that class II group had the most constricted area which was statistically low when compared to the other two groups (table 5).

Table 6 gives the intergroup comparison of the relevant significant data. NP volume was higher in class I when compared to the other two groups. NP length was greater in class II group whereas OP width was greater in Class III group compared to the other two group.

| Table-4: Comparison of nasopharyngeal (NP) width between different skeletal patterns using KRUSKAL WALLIS TEST | | | | | | |
|---|---|---|---|---|---|---|
| | NP length | | | NP width | | |
| Group | Mean (μ) mm | Std. Deviation (σ) mm | Asy sig | Mean (μ) mm | Std. Deviation (σ) mm | Asy sig |
| A CLASS I | 13.290 | 3.5784 | | 17.955 | 3.1198 | |
| B CLASS II | 15.825 | 3.4507 | 0.043 | 20.180 | 4.3339 | 0.195 |
| C CLASS III | 13.830 | 3.0993 | | 18.660 | 4.1949 | |

## Discussion

Respiration through upper airway is a vital functional process that can have a profound influence on normal craniofacial development.[3] The close relationship between the pharynx and the dentofacial structures can therefore cause a mutual interaction between the pharyngeal structures and the dentofacial pattern.[4] The size of nasopharyngeal airway space is of importance in its relationship to the morphology of face as the reduction of nasopharyngeal airway space makes nasal breathing difficult and mouth breathing necessary.[5] Upper airway dimension is one of the contributing factors for airway collapsibility in sleep disordered breathing.[6]

Airway abnormality and obstruction can have a profound effect on development of oro-dental structures, hence a thorough knowledge of different airway dimensions in various skeletal patterns is important for proper diagnosis and treatment planning in orthodontics. Thus, the study was undertaken with the aim of evaluating and comparing different airway dimensions in three skeletal malocclusion groups.

When nasopharyngeal length was compared between three groups it showed remarkable variation between three groups with a P-value 0.043 and skeletal class II group showed higher NP length (15.825mm) when compared to class I (13.290mm) and class III groups (13.830mm) (Table 4). The multigroup comparison for NP length using Mann Whitney U test revealed statistically significant reduction in NP length for class I group when compared to class II and class III groups (Table 6).

The increase in NP length could also be due to increased maxillary alveolar height commonly seen in skeletal class II group. The results of this study contradict with study by Zetu et al where NP length decreased in class II subjects.[7] According to Zetu et al NP length increases with increase in cranial base angle and decreases when jaw angle decreases.[7]

The nasopharyngeal width was assessed and compared between three groups and it showed no statistically significant difference with highest NP width for class II groups (20.180mm) when compared to class I (17.955mm) and class III groups

(18.660mm) (table 4). This could be due to higher allowance for expansion of nasopharynx in

| Table -5: Comparison of most constricted area in the three skeletal patterns by Kruskal Wallis test | | | | |
|---|---|---|---|---|
| Groups | N | Mean (μ) $mm^2$ | Std. Deviation (σ) | Asym sig |
| A CLASS I | 20 | 146.90 | 103.30 | |
| B CLASS II | 20 | 106.10 | 105.13 | 0.037 |
| C CLASS III | 20 | 187.30 | 104.38 | |

skeletal class II with anteriorly positioned maxilla. This result was in agreement with studies by Kirjavainen et al, El H et al and contradict with the study by Ceylan and Oktay where the findings indicated a decrease in NP area in class II groups when compared to class I and class III groups.[4,8,9]

volume in class I groups when compared to class II and III groups but with a statistical significance unlike the study by Kim et al in which class II group was found to have statistically significant NP volume.[9,10,11,12] The decrease in NP volume in class III subjects in the present study could be attributed to the decreased maxillary anteroposterior and vertical development of maxilla in class III skeletal base.

| Table -6: Mann whitney U test for statistical significance of variables: OP-oropharyngeal; NP- nasopharyngeal; MinAx- most constricted area | | | | | |
|---|---|---|---|---|---|
| **Groups** | Variables | Mann whitney U | Wilcoxon W | Z | P |
| **Class I & II** | NP volume | 138.000 | 348.000 | -1.677 | 0.094 |
| | NP length | 116.500 | 326.500 | -2.260 | 0.024 |
| | MinAx | 158.500 | 368.500 | -1.123 | 0.261 |
| | OP width | 155.000 | 365.000 | -1.220 | 0.231 |
| **Class I & III** | NP volume | 96.000 | 306.000 | -2.813 | 0.005 |
| | NP length | 172.500 | 382.500 | -0.745 | 0.456 |
| | MinAx | 153.500 | 363.500 | -1.258 | 0.211 |
| | OP width | 53.000 | 263.500 | -3.983 | 0.000 |
| **Class II & III** | NP volume | 154.000 | 364.000 | -1.244 | 0.213 |
| | NP length | 128.000 | 338.000 | -1.949 | 0.051 |
| | MinxAx | 102.000 | 312.000 | -2.651 | 0.007 |
| | OP width | 28.500 | 238.500 | -4.648 | 0.000 |

The nasopharyngeal volume was compared among the three groups. The P-value (0.016) depicted a significant difference statistically with a higher NP volume in class I (7374.05$mm^3$) when compared to class II (6090.85$mm^3$) and class III (5204.45$mm^3$) groups (Table 3). In the multigroup comparison for NP volume using Mann Whitney-Wilcoxon test, class I had statistically higher NP volume than other two groups whereas there was no statistical significance between class II and class III groups (Table 6).

The nasopharyngeal volume in the study correlates with the study by El et al and Ucar et al where there was a higher NP

In the oropharyngeal dimension, oropharyngeal length was found to be higher in class II group (35.270mm) when compared to class III (34.825mm) and class I (34.515mm) groups and the P-value was 0.834 with statistical insignificance (Table 2). The increase in oropharyngeal length in class II subjects may be due to increased alveolar growth of maxilla leading to increased facial height commonly seen in class II subjects. This can be correlated with the study of Shastri et al who studied the oropharyngeal length in various facial patterns.[13]

When oropharyngeal width was compared for three groups (Table 2), the P-value obtained was 0.000 which showed high statistically significant difference between three groups with skeletal class III group being highest (25.600mm) followed by class I (21.880mm) and class II groups (20.885mm). The multigroup comparison for OP width using Mann Whitney U test revealed a high statistically significant reduction in class II group when compared to class I and class III groups.

The OP width was seen least in class II groups and class III being widest. This could be due the alteration in mandibular position anteroposterior as well as hyoid bone in class II as well as class III subjects. Adamidis and Spyropoulos stated that hyoid bone is in a more forward position in class III subjects, which could be reason for the greater OP width in class III individuals.[14] The increased width of oropharynx in class III subjects could be attributed to the increased width or broader mandible and also due to anteriorly positioned mandible.

The oropharyngeal (OP) volume was higher in class III group (17038.45mm$^3$) when compared to class I (10061.40mm$^3$) and class II groups (9987.20mm$^3$). The intergroup comparison showed statistically insignificant difference in oropharyngeal volume withp –value of 0.361. The results correlated with the study done by Hakan et al and Kim et al where the oropharyngeal volume was statistically smaller for subjects with retruded mandibular position as in class II.[9,10,12] Kim et al stated that airway volume was lesser in retrognathic subjects compared to patients with normal skeletal relationship.[12] This was due to the more rearward position of mandible with respect to base of cranium which tends to make the Oropharyngeal volume small.

Short or backwardly positioned mandible might push the soft palate and tongue into pharyngeal space causing reduction in volume of oropharynx. Narrow pharyngeal airway space could be due to different growth patterns as well as the vertical growers can have smaller pharyngeal space due to backward growth rotation which can increase facial height and adenoid obstruction is most common among long face individuals.[14] Class II subjects with retruded mandibular position showed higher apnoea index and respiratory disturbance index.[15,16,17,18] In the present study class II subjects have lesser OP volume which is statistically insignificant.

Most constricted area (minAx) was calculated and the P-value 0.037 indicated statistically significant difference between the groups with maximum constriction in class II groups (106.10mm$^2$) when compared to class I (146.90mm$^2$) and class III groups (187.30mm$^2$) (Table 5). Multigroup comparison for most constricted area (minAx) using Mann Whitney U test showed statistically significant difference with class II having most constriction when compared to class I and class III groups (Table-6).

There was a definite correlation between most constricted area and OP volume as mentioned in the study by El and Palamo as the maximum constriction was seen in class II groups which had the least oropharyngeal volume due to the retruded position of the mandible.[10] Most constricted area showed a definitive explanation for variability in OP volume in different malocclusions. When the results are taken into consideration, the sites of upper airway restriction are of marked clinical significance in comprehending the airway size and volume and planning treatment as the constriction of airway could be due to backwardly driven tongue due to retrognathic mandible in class II subjects.

Oropharyngeal (OP) and nasopharyngeal (NP) areas were assessed using Dolphin 3D software. The skeletal class III group had highest oropharyngeal area (469.75mm$^2$) when compared to class I (404.25mm$^2$) and class II (386.10mm$^2$) whereas class II had highest nasopharyngeal area (269.60mm$^2$) when compared to class I (233.05mm$^2$) and class III groups (242.65mm$^2$) (Table 1,3). The results correlate with study by Ceylan and Oktay where there is a decrease in oropharyngeal area with increase in ANB angle.[4] This could be due to disparity in location of tongue and mandible in class II malocclusion when compared to other skeletal dispositions. The nasopharyngeal area measurements correlate with investigations by Kerr.[19] There was larger nasopharyngeal area in class II malocclusion group when compared to class I group. NP area measurement in this study contradicts with the study by Mergen and Jacobs where they inferred that the NP dimensions were higher in normocclusion when compared to class II.[20]The increase in NP area in class II groups could be due to increase in anterior facial height according to Ceylan and Otkay et al.[4,18]

The most constricted area (MinAx) is correlated to OP volume in all three skeletal patterns and there was a positive correlation with statistical significance between class I (P value-0.003) and class III groups (P value-0.007) suggestive of increase in MinAx area with increase in OP volume(Table 5).

Hence the results reveal that among the parameters evaluated NP volume; NP length, OP width and most constricted areas were statistically significant between groups. Nasopharyngeal volume was lowest in skeletal class III groups when compared to class I and class II groups with statistically significant difference between groups. This could be due to the retruded position of the maxilla. The nasopharyngeal length showed a statistically significant difference between three groups with class II group being highest which could be due to anteriorly positioned maxilla. The oropharyngeal width showed a statistically significant difference between groups with class III being widest when compared to class I or class II groups. The most constricted area in pharyngeal airway could be seen in class II subjects due to retruded position of mandible which reduces the space for tongue position leading to posterior positioning of tongue and thus leading to constriction in airway.

Thus, the study reveals that nasopharyngeal volume had shown a reduction in class III groups when compared to class I and class II groups with statistical significance. Among pharyngeal dimensions, class III subjects showed significant increase in oropharyngeal width and nasopharyngeal length.

This study did not include nasal turbinates and nares in the evaluation of nasopharyngeal dimensions. Gender was not included as criteria for comparing the pharyngeal volumes and dimensions. Body Mass Index, which is a factor that affects the oropharyngeal volume was not considered under evaluation. Stratification by vertical dimensions taking into account the growth pattern could have been taken into account.

Positional changes of hyoid bone, variations in gonial angle and the effect of dimensional changes of uvula on pharyngeal measurements needs further investigation.

## CONCLUSION

The following conclusions were arrived from the study: 1. Oropharyngeal width was highest in class III subjects which were highly significant. It could be attributed to the increased width or broader mandible in class III subjects and due to anteriorly positioned mandible.

2. Nasopharyngeal length was statistically higher in class II subjects which could be attributed to increased maxillary alveolar height commonly seen in class II subjects.

3. Most constricted area was the maximum in class II subjects which was significant. This may be caused by backwardly driven tongue due to retrognathic mandible in class II subjects.

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