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Vol 11 No 1 (2023) DOI 10.5195/d3000.2023.245

# Evaluation of Tongue Volume and Airway Volume in Skeletal Class I and Class II Patients using Cone Beam Computed Tomography- A Cross Sectional Study

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## Abstract

**BACKGROUND:** The volumetric relationship between the tongue and the oral cavity is an important factor in tooth alignment and occlusion. The aim of this study was to evaluate the difference in tongue and airway volume in skeletal Class I and Class II malocclusion.

**MATERIALS AND METHODS:** The CBCT data which comprised of 30 skeletal Class I and 30 skeletal Class II was stored in DICOM format. Tongue volume and airway volume was analyzed with the help of 3D dolphin software. Values obtained were subjected to statistical analysis with help of SPSS.

**RESULTS:** Skeletal Class I pattern had more tongue volume with a mean of 45.32 $mm^3$ than skeletal Class II pattern with mean value of 40.27 $mm^3$ with P value of <0.001. Skeletal Class I pattern has more airway volume with a mean of 15058.6 $mm^3$ than patients with skeletal Class II pattern with mean value of 12458.8 $mm^3$ with a P value of 0.003. A P value of 0.001 indicated that there is a strong correlation between the tongue volume and airway volume in both skeletal Class I and skeletal Class II subjects.

**CONCLUSION:** The volume of tongue and airway was greater in skeletal Class I malocclusion compared to skeletal Class II malocclusion. There exists a positive correlation between the tongue volume and airway volume in both the skeletal patterns.

**KEYWORDS:** airway volume; Class I skeletal malocclusion; Class II skeletal malocclusion; Dolphin software; tongue volume

Citation: Thomas Abraham, J et al. (2023) Evaluation of Tongue Volume and Airway Volume in Skeletal Class I and Class II Patients using Cone Beam Computed Tomography- A Cross Sectional Study
Dentistry 3000. 1:a001 doi:10.5195/d3000.2023.245
Received: October 5, 2021
Accepted: April 4, 2023
Published: October 13, 2023

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## Introduction

According to the equilibrium theory, teeth alignment is influenced by the tongue and the lip [1]. The tongue is a powerful muscular organ which is centrally located within the oral cavity and has the ability to affect the position of the teeth and the surrounding structures [2]. Abnormality of either function or position of tongue can lead to change in the surrounding dentoalveolar

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structures and skeleton. In cases of mandibular prognathism, the tongue occupies the floor of the mouth, and can be bulky, hypotensive, and projected [3]. On the other hand, when mandibular retrognathism occurs, with reduction in the anteroposterior space, the usual tongue position shows a lowered apex with dorsum more elevated, which can be located between the dental arches in case there is a concomitant maxillary retrusion [4].

Respiratory function and the upper airway are very important for orthodontic diagnosis and treatment planning as varied breathing function could influence facial growth and morphology [3,5]. Oropharyngeal and nasopharyngeal structures play a role in the development of the dentofacial complex [5]. According to the functional-matrix hypothesis proposed by Melvin Moss, soft-tissue units guide the hard tissues to an extent. It has also been suggested that an increase in the volume of soft tissues induces osteogenic reaction at the growth site of the bone [5].

Patient exhibiting Class II skeletal base tend to have smaller airway volume, but the tongue volume remains a topic of debate. There are 2 schools of thought regarding this issue. The first is that the tongue adapts to the retrognathic mandible, which leads to the posterior positioning of tongue as well as the inferior and posterior displacement of the hyoid bone. But studies have shown that although the hyoid bone adapts to the tongue position, there is always a tendency for the hyoid bone to relapse to a superior position which eventually can cause narrowing of airway leading to obstructive sleep apnea in Class II skeletal base. The other concept regarding the same is that the mandible adapts to the high-volume tongue which eventually leads to increase in the inter molar distance in Class II skeletal base [6]. This debate has been longstanding. Hence determining the size of the tongue in different facial morphological variants can be useful [3].

Dentistry has witnessed tremendous advances and with these advances, the need for use of precise diagnostic tools, especially imaging methods, has become mandatory. Cone beam CT technology (CBCT) has emerged as a potential alternative to Magnetic Resonance Imaging (MRI) and CT scanning to obtain complete, fast, and detailed images at a relatively modest cost. The advantages of CBCT include lower radiation dose which causes less radiation hazards to the patients [7]. Hence the present study was done to evaluate the tongue volume in skeletal Class I and Class II subjects and its association with the airway volume using CBCT.

## Material and Methods

This cross-sectional study conducted using Cone Beam Computed Tomography scans of 60 patients. The scans were obtained from the patient archives from ORAL D SCAN center and from the Department of Oral Medicine and Radiology FDS, RUAS. The study protocol was approved by the Ethics review committee of Ramaiah University of Applied Sciences. The research project protocol number was EC-2020/UG/075 and approval date was 01/09/2020.

The sample size was estimated using the G Power software v. 3.1.9.2. Considering the effect size to be 80%, power of the study at 85% and the margin of the error at 5%, the sample size needed was calculated to be 60.

The scans which were selected for the study were of those patients whose CBCTs were made placing the patient in natural head position during the image acquiring procedure with the lips and tongue relaxed so that the borders delineating the tongue shape could be obtained. The patients whose scans were used from the institute archives had all given informed consent for their scans to be used for research purposes. Care was taken to avoid any involuntary movements like swallowing, which would have caused kinetic defects in CBCT slices. All the scans in the archives were made using the same machine and using Carestream software (Carestream 9300) with parameters of 6.3 mA, 90 kvp, and 300 microns resolution with full field of view (FOV) of 17x13.5 cms. The age of the patients ranged from 14- 20 years, and this included 39 females and 21 males.

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Inclusion criteria applied for the study were: CBCT of male or female patients in the age group ranging between 14- 20 years, no history of orthodontic treatment or facial surgery, CBCT was taken with patient biting in centric occlusion and no enlarged tonsil or adenoids present. The exclusion criteria applied were: CBCT with bite block placed, Congenital anomalies like cleft lip and palate.

Patients were categorized into skeletal Class I and Class II based on following cephalometric parameters[8, 9]: ANB value: ANB angle ranging from $2^0$-$4^0$ were classified as Class I skeletal pattern and ANB value greater than $4^0$ were classified as Class II skeletal pattern [8]. Witt's appraisal: AO ahead of BO greater than 2mm was classified as Class II skeletal pattern [9]; Angle's molar relation; Overjet: overjet of 2-4mm was considered as skeletal Class I pattern and greater than 4 mm was considered as skeletal Class II pattern. 60 CBCTs (30 Class I, 30 Class II) which fulfilled all the inclusion and exclusion criteria, were selected for the study.

The CBCT data which comprised of 30 skeletal Class I and 30 skeletal Class II was transferred to a computer which stored the data in the Digital Imaging and Communications in Medicine (DICOM) format. A 3D data and 3D coordinate system were constructed using Dolphin 3D software. (Dolphin software, version-11.96, Dolphin Imaging & Management solutions, Chatsworth, CA)

The tongue volume determination was carried out as follows. Landmarks were considered both in lateral and transverse plane to delineate the borders of the tongue from the adjacent structures. Once the image in the lateral view was cropped it was then assessed in the transverse view to obtain the final 3D image. The obtained cropped 3D image of the tongue was subjected to volumetric analysis using 3D Dolphin software (version 11.96) in the computer. The volume of the tongue was hence displayed in cubic millimeters by the software. The boundaries considered in the lateral view aspect were (Figure 1) anterior point: Incisal point of maxillary incisor, Superiorly: ANS – PNS plane, Postero-superiorly: PNS point, Postero-inferiorly: At the junction of C 2 and C 3, Inferiorly: CEJ level of second molar to first premolar. The boundaries considered in the transverse plane are: (Figure 2) Laterally: Borders delineating the alveolar bone and the soft tissue, Posteriorly: borders delineating the soft tissue and the airway pathway (Figure 3).

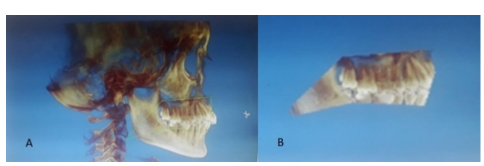


***Figure 1.*** *Boundaries marked for cropping to obtain the borders of the tongue from lateral view aspect (A); image obtained after cropping (B).*

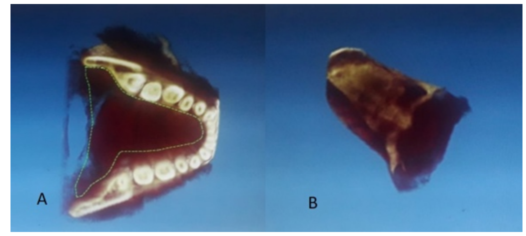


***Figure 2.*** *Boundaries delineating alveolar & bone airway from the tongue (A); cropped 3D image (B).*

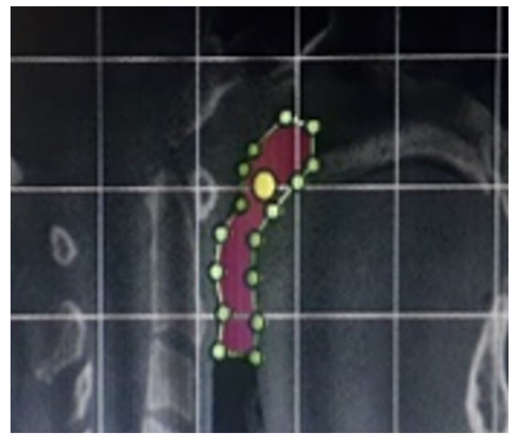

***Figure 3.*** *Boundaries delineating the airway from the adjacent structures.*

The airway volume determination was carried out as follows. To obtain airway volume using Dolphin 3D, it was required to define the outline of the airway. Seed points were placed in the target airway. Seed points denote densities which represents the airway. The volume of the airway was displayed in cubic millimeters. The boundaries of the airway: Superior- Superior tip of nasopharyngeal airway, Anterior border-Vertical plane through Posterior Nasal Spine, perpendicular to the sagittal plane, Posterior border-Posterior wall of the pharynx, Inferior border- Plane tangent to the most medial projection which is in the caudal aspect of the third cervical vertebrae at right angles to the sagittal plane.

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SPSS (SPSS Inc., Chicago v 18.5) software packages were used for data entry and analysis respectively. The results were averaged (mean + standard deviation) for continuous data and number and percentage was used for dichotomous data. The student 't' test was used to determine if there was a statistical difference. Pearson correlation coefficients were calculated to determine if there was any correlation between the Tongue Volume and the airway volume.

## Results

The current study consisted of 60 CBCT samples of skeletal Class I and Class II subjects. Among the 60 samples, the percentage distribution was 68.3% females and 31.7% males as shown in figure 4.

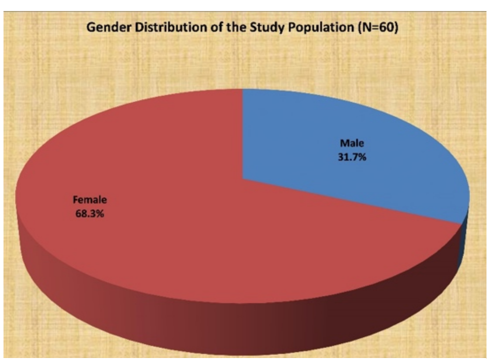


***Figure 4.*** *Pie diagram representing gender distribution among the study samples.*

Table 1 depicts the distribution of males and females in skeletal Class I and Class II and there was no statistically significant difference seen. Table 2 shows that the mean age of males and females in skeletal Class I case was 17.4 years and 16.9 years respectively. P value was 0.448 which indicates statistically insignificant difference. The mean age of males and females in skeletal Class II cases were 17.7 years and 18.3 years respectively. P value was 0.420 which indicated statistically insignificant difference.

**Table 1:** Gender distribution amongst the individual skeletal pattern and its significance.

| Skeletal pattern | Gender | | Total | $\chi^2$ value | P value |
|---|---|---|---|---|---|
| | Male | Female | | | |
| Class 1 | 9 | 21 | 30 | 0.077 | 0.781 |
| | 30.0% | 70.0% | 100.0% | | |
| Class 2 | 10 | 20 | 30 | | |
| | 33.3% | 66.7% | 100.0% | | |
| Total | 19 | 41 | 60 | | |
| | 31.7% | 68.3% | 100.0% | | |

**Table 2:** Table showing age distribution in skeletal Class I and Class II subjects.

| Skeletal Pattern | Gender | N | Mean Age | SD | Min. | Max. | t value | P value |
|---|---|---|---|---|---|---|---|---|
| Class 1 | Male | 9 | 17.4 | 2.404 | 15 | 21 | 0.592 | 0.448 |
| | Female | 21 | 16.9 | 1.682 | 15 | 20 | | |
| | Total | 30 | 17.0 | 1.903 | 15 | 21 | | |
| Class 2 | Male | 10 | 17.7 | 2.312 | 14 | 21 | 0.670 | 0.420 |
| | Female | 20 | 18.3 | 1.658 | 14 | 21 | | |
| | Total | 30 | 18.1 | 1.882 | 14 | 21 | | |

Table 3 depicts the comparison of mean values of Tongue Volume in skeletal Class I and Class II pattern. Patients with skeletal Class I pattern had a significant more tongue volume with a mean of 45.32 $mm^3$ compared to patients with skeletal Class II pattern who had mean value of 40.27$mm^3$ respectively with p value of <0.001. Table 4 shows the comparison of mean values of Airway volume between skeletal Class I and Class II pattern. Patients with skeletal Class I pattern have large airway volume (with a mean of 15058.6 $mm^3$) compared to patients with skeletal Class II pattern (with mean value of 12458.8$mm^3$) respectively with p value of 0.003.

Table 5 shows the correlation between Tongue Volume and airway volume in skeletal Class I and Class II pattern. The P value of 0.001 indicates that there is a strong correlation between the tongue volume and airway volume in skeletal Class I and skeletal Class II subjects. Also, R value of 0.4596 depicted strong positive correlation between tongue volume and airway volume in skeletal Class I subjects. The R value of 0.3211 depicted strong positive correlation between tongue volume and airway volume in skeletal Class II subjects.

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**Table 3:** Comparison of Mean values of Tongue Volume in skeletal Class I and Class II pattern.

| Skeletal pattern | N | Mean | SD | Median | Min. | Max. | Mean Diff | SE | 't' value | P value |
|---|---|---|---|---|---|---|---|---|---|---|
| Class 1 | 30 | 45.32 | 2.517 | 45.40 | 39.83 | 49.46 | 5.052 | 0.545 | 9.270 | <0.001 |
| Class 2 | 30 | 40.27 | 1.604 | 40.25 | 37.54 | 42.92 | | | | |

**Table 4:** Comparison of Mean values of Airway volume between skeletal Class I and Class II pattern.

| Skeletal pattern | N | Mean | SD | Median | Min. | Max. | Mean Diff | SE | 't' value | P value |
|---|---|---|---|---|---|---|---|---|---|---|
| Class 1 | 30 | 15058.6 | 3960.467 | 14,241.0 | 9569 | 23367 | 2599.7 | 836.623 | 3.107 | 0.003 |
| Class 2 | 30 | 12458.8 | 2304.961 | 12,716.0 | 8150 | 16834 | | | | |

**Table 5:** Correlation between Tongue Volume and airway volume in skeletal Class I and Class II pattern.

| Skeletal pattern | | | Airway volume |
|---|---|---|---|
| Class 1 | Tongue Volume | Correlation | 0.678 |
| | | P value | <0.001 |
| Class 2 | Tongue Volume | Correlation | 0.567 |
| | | P value | 0.001 |

## Discussion

The present study was done to evaluate the tongue volume and airway volume in skeletal Class I and Class II malocclusion and also to find if there is a correlation between the tongue volume and airway volume in the respective skeletal pattern. With the advent of imaging techniques like CBCT, diagnosis and treatment planning is greatly supplemented, thus making 3D analysis of maxillofacial skeleton and soft tissues possible [10]. The usual method of evaluating the tongue volume was Magnetic Resonance Imaging (MRI), since MRI is the gold standard for measuring soft tissues. 3D Dolphin Software is considered as the gold standard method for evaluating the airway volume [11]. Currently numerous imaging software's are available for evaluating the tongue volume and the airway volume. Mimics (Materialize Interactive Medical Image Control System) is an image processing software for 3D design and modeling. It is used to create 3D surface models from stacks of 2D image data. Weissheimer et al compared 6 imaging software's and concluded that Mimics, Dolphin3D, Osiri X and ITKsnap were similar and more accurate than In vivo Dental and On Demand for upper airway assessment [12].

In the present study, the ANB angle was used to identify the skeletal pattern of the samples. Using ANB alone for identification of skeletal pattern is unreliable as it is subjective to many variables like nasion area morphology, vertical dimension of the face, anterior cranial base inclination, and inclination of the jaws. Using only ANB would have

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confounded the study, as the location of point A and point B will have an impact on the angle. Thus, in addition to ANB values, Witt's appraisal and molar relationship were also taken into consideration for identifying the skeletal pattern [13].

The age group of the sample consisted of both adolescents and adults, despite the fact that airway volume varies with age. Kollias et al had performed a long term follow up study and had concluded that between 20 to 50 years of age, there is a gradual decrease of airway dimension noted both behind the tongue as well as and posterior to the soft palate [14]. In other studies, it was reported that pharyngeal structures continue to grow rapidly until 13 years of age and a quiescent period was noted between the ages of 14 to 18 years which meant that the variation of airway size of this age group was minimal [15, 16]. Thus, in this study, age was standardized by taking samples with ages ranging from 14 to 20 years to minimize variation due to growth.

The volume of tongue is determined by factors such as size of mandibular arch, maxillary width, vertical facial height and combined vertical and horizontal position of chin and symphysis. It has been an accepted fact that increases in volume of soft tissue induces increase in osteogenesis at the growth site of the bone. Earlier the volume of tongue was measured with the help of lateral cephalogram which basically determines the 2-dimensional size of the tongue. Lui et al evaluated the volume of tongue with the help of contrast agent such as barium [17]. Vig and Cohen compared sagittal area of the tongue to that sagittal area of the oral cavity with the help of bony landmarks [18]. Few other studies have evaluated the size of the tongue by direct measurement but those were not able to measure the posterior limit of the tongue. Bandy and Hunter measured the volume of tongue by water displacement method [19]. In the present study, the tongue volume was measured with defined landmarks based on a previous study conducted by Liegeois et al.[20] In our study the tongue volume was measured with the help of 3D dolphin software. Studies have proved that Dolphin imaging was effective in measurements and had better prediction compared to the other imaging software [7].

The influence of oral function on growth has been a topic of discussion in orthodontics for decades. Initial studies related to airway were started in the early 1970s. Since then, it has been a subject of great interest for the orthodontist to evaluate any correlation associated with airway and structures associated with it, especially the tongue because of its close proximity [21]. In this study the pharyngeal airway was considered as a whole with defined landmarks instead of dividing it into upper middle and lower compartments. This was done to ensure ease of computing and to avoid errors in volume determination by adding more landmarks to the study. This was done in accordance with the study by Kyung Min OH [22].

In this study the volume of airway was greater in skeletal Class I malocclusion. This was in accordance with the studies conducted by Palamo et al who proved that the oropharyngeal and nasopharyngeal airway volumes of Class II patients were smaller when compared with Class I and Class III patients [23]. Similarly another study conducted by Deepthi et al had proved that there was a negative correlation between airway volume with ANB angle, implying that class II skeletal base patients had lesser airway volume [24]. Studies conducted by Frieties et all had shown that there was no statistically significant difference in airway volume in different malocclusion but there was statistically significant difference in patients exhibiting vertical and horizontal growth pattern where vertical growth pattern had lesser volume of airway as compared to horizontal [25]. It was also observed that the position of the mandible with respect to the cranial base had an effect on the pharyngeal airway volume. This may be due to the fact that if the Class II skeletal pattern is caused by the mandible being retrognathic, the overall oropharyngeal airway space will be reduced. In the current study, the distinction has not been made based

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on whether the skeletal Class II pattern is caused by mandibular retrognathism of by maxillary prognathism. The degree of jaw discrepancy was relatively less in the selected samples as the ANB value of the selected Class II samples ranged between $5^0$-$7^0$. Hence the effect of significant mandibular retro position requires further investigation as it might have further influence on airway morphology and volume.

In the present study the ‘r’ value of 0.4596 depicts strong positive correlation between tongue volume and airway volume in skeletal Class I subjects, similarly ‘r’ value of 0.3211 indicates strong positive correlation between tongue volume and airway volume in skeletal Class II subjects. There was not much literature found comparing the correlation between tongue volume and airway volume in skeletal Class I and skeletal Class II.

In this study it was found there was a statistically significant difference between the tongue volume in skeletal Class I and skeletal Class II malocclusion indicating that the tongue volume was greater in skeletal Class I malocclusion compared to skeletal Class II malocclusion. This was in agreement with a previous study’s findings [26]. In another study it was shown that that there was no statistical difference between size of the tongue and airway volume in relation to different skeletal pattern [27]. This was in contradiction to the present study where the volume of tongue and airway was greater in skeletal Class I samples compared to skeletal Class II samples.

These limitations of this study were that the sample did not have an equal proportion of males and females and was limited with respect to age range considered. The future prospects for research are to conduct a similar study in a larger sample size, to include different age brackets and compare between them, and to compare between sexes.

## Conclusion

The present study was concluded that the mean tongue volume ($45.32mm^3$) and mean airway volume ($15058.5mm^3$) were greater in samples exhibiting skeletal Class I malocclusion compared to Class II samples. A strong positive correlation exists between tongue volume and airway volume in skeletal Class I and skeletal Class II subjects.

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