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Airway Analysis By Lateral Cephalogram And Computed Tomography- A Retrospective Study

Dr. Nilesh Pagaria[1], Dr. S. M. Kanade[2], Dr. Shashank Katiyar[3*], Dr. Swalpa Agrawal[4], Dr. Priyadershini Rangari[5]

[1]Professor and Head, Department of Dentistry, Sri Shankaracharya Medical College, Bhilai, Durg, Chhattisgarh

[2]M.B.B.S., M.S.(ENT), Head And Associate Professor, Department of Otolaryngology, Rajiv Gandhi Medical College And Chhatrapati Shivaji Maharaj Hospital, Thane, Maharashtra, [3*,4]MDS,Orthodontics And Dentofacial Orthopedics, [5]MDS,Oral Medicine And Radiology, [3,5]Assistant Professor, Department of Dentistry, Sri Shankaracharya Medical College, Bhilai, Durg, Chhattisgarh

Correspondence Author: Dr. Shashank Katiyar**,** Assistant Professor, Department of Dentistry, Sri Shankaracharya Medical College, Bhilai, Durg, Chhattisgarh

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Abstract

Objectives**:** The present study was conducted to evaluate the interaction between craniofacial structures and airway space on Lateral Cephalogram and the volume of airway space on CT along with soft palate and tongue and to compare its reliability.

Material and methods**:** A total of 45 patients, were equally divided into three different groups. Angular measurement, hard tissue linear measurement, linear measurement of upper airway space and soft tissue, measurement of upper airway and soft tissue area were calculated on Cephalogram and CT scan.

Observations**:** In the present study upper airway space and area was measured and compared in three different ANB groups and found that there is decrease in MAS, IAS and Upper airway area i.e. nasopharynx, oropharynx & hypopharynx area with increase in ANB angle, there is increase in upper airway space i.e SPAS, MAS & IAS in normal ANB group (2-4°) compared with other two groups.

Results and interpretation**:** The leaf shape of soft palate was found in maximum subjects in our population with percentage of 31.3%, followed by crook shape (28.9%), rat tail (24.4%), S shape (11.1%) and butt shape (4.4%). The results of airway obtained in CT shows more higher statistical significance in relation to upper airway and the coefficient of variation percentage showed that CT airway volume shows more variability than corresponding airway area.

Statistical difference was significant for PFH (p=0.02) and Oropharyngeal area (p=0.04) and highly significant for Nasopharyngeal area (p=0.01), Superior posterior airway space (SPAS) i.e (p=0.01) and PFH/AFH (p=0.01) suggesting with increase in PFH, there is increase in airway space i.e mainly SPAS and with increase in AFH, Oropharynx and soft palate area increases and with increase in ALFH, nasopharyngeal area increases.

Thus this study concluded that facial height has an influence on nasopharynx and tongue area.

Keyword: Nasopharynx, Oropharyngeal, Cephalometric Analysis, Computed Tomography, Upper Airway.

Introduction

The form and function of the pharynx has been of interest to researchers for many years. While the typical growth pattern of the pharynx in children and adolescents has been elucidated using growth study material,[1] Radiographic cephalometric analysis has been used extensively to evaluate the growth & malformations of the dento facial skeleton.[2]

The pharynx is a median fibromuscular tube that extends from the base of the skull. It is made up of the sphenoid and the occipital bones to the level of the sixth cervical vertebra, where it is continuous with the oesophagus.[3] It seems to be a general belief that the oropharyngeal (OP) and nasopharyngeal structures play roles in the development of the dentofacial complex.[4]

The nasopharynx and the oropharynx have significant locations and functions because both of them form a part of the unit in which respiration and deglutition are carried out and they include lymphoid tissue in their structures. Nasal obstruction secondary to hypertrophied inferior turbinates, adenoidal pad hypertrophy, and hypertrophy of the faucial tonsils can cause chronic mouth breathing, loud snoring, obstructive sleep apnea, excessive daytime sleepiness. In this situation, a number of postural changes, such as open mandible posture, downward and forward positioning of the tongue and extension of the head can take place. If these postural changes continue for a long period, especially during the active growth stage, dentofacial disorders at different levels of severity can be seen, together with inadequate lip structure, long face syndrome, and adenoidal facies.[5]

According to the functional-matrix hypothesis proposed by Moss, soft-tissue units guide the hard tissues to an extent. The etiology of malocclusions is believed to be multifactorial. It could be considered erroneous to associate malocclusions only with breathing mode. Since the airway is assumed to play a role in dentofacial development, several studies tried to correlate patients with normal nasorespiratory functions with different malocclusions and airway dimensions.[4]

In many studies, it was demonstrated, that there is a significant relationship between the pharyngeal structures and both - dentofacial and craniofacial structures at varying degrees.[6] Airway obstruction can determine abnormal development of the facial pattern. The influence of the soft tissues in craniofacial growth therefore justifies the relevance to the orthodontic diagnosis and the treatment plan.[3]

In the past, the upper airway was evaluated by differential pressure measurements, allowing calculation of upper airway resistance and electromyographic (EMG) activity of various upper airway muscles. Those modalities, however, do not provide anatomical representation of the soft tissue structures surrounding the airway. Knowledge of the morphology and mechanical behavior of the soft tissue structures is essential for a more complete understanding of the physiology of the upper airway, such information has been provided with imaging technology.[8]

The techniques of lateral cephlometry and CT scanning are more commonly used.

The use of lateral cephalometric radiographs to evaluate the upper airway is somewhat limited as it has been a major issue in studies assessing cross-sectional areas and volumes of the airway[4] and provides only 2-dimensional images of the nasopharynx. The arrival of 3D computed tomography (CT) promised to alleviate this problem. In addition, despite imaging limitations of lateral cephalometry especially in the transverse plane, CT can provide assessment of the relationship between craniofacial characteristics and nasopharyngeal conditions, along with providing some useful information in estimating tongue and airway volume.[10]

The posture and the position of the head can also modify the airway space. The airway decreases in retropalatal width between radiographs taken in supine and upright positions of the same adult. We also believe that a 2-dimensional (2D) view of the airway space does not give an accurate indication of the complexity of this structure or its true size.[11]

In our study we used Lateral cephalogram and three-dimensional airway CT to investigate the pharyngeal size at different levels i.e Nasopharynx, Oropharynx & Hypopharynx of patients Shaving different dentofacial skeletal patterns, also perform dimensional analysis of the soft palate and tongue to determine the linear, volumetric, and cross-sectional area measurements to evaluate interaction of upper airway size and dentofacial structures. The correlation of upper airway and soft tissue measurements with neck circumference & BMI (Basal Metabolic rate) will be elucidated to evaluate the predictor of sleep apnea and the morphology of soft palate will be examined on lateral cephalogram to evaluate etiology of obstructive sleep apnoea syndrome and avelopharyngeal closure in cleft palate individuals.

Aim of this study was to evaluate the interaction between craniofacial structures and airway size (space and area) and volume of airway space along with soft palate and tongue on lateral cephalogram and Computed tomography.

Material And Methods

It was a randomized controlled, single blind study of 45 patients referred for Lateral cephalogram and Computed tomography (C.T) in the outpatient Department Of Otolaryngology, Rajiv Gandhi Medical College and Chhatrapati Shivaji Maharaj Hospital, Thane, Maharashtra, India. The study was performed in one year period from January 2013- to January 2015.

The patients who were diagnosed with class i, ii & iii malocclusion and were advised for lateral cephalogram and computed tomography (c.t), patients more than 18 years were included in the study.

Exclusion criteria was edentulous patients, patients with cross bite (posterior), patient less than 18 years or more than 25 years of age and patient who were undergoing orthodontic treatment and patient with any airway problem large adenoids, tonsils etc.

Lateral Cephalometric Analysis:

Angular Measurement (Figure 3) by cephalogram

1. **SNA**: Angle formed between plane constructed from Nasion (N) to Sella and Point A.
2. **SNB**: Angle formed between plane constructed from Nasion (N) to Sella nd Point B.
3. **ANB**: Is the difference between SNA and SNB angle.
4. **Upper incisor linear measurement-**The anterior angle between the long axis of the incisor and palatal plane is measured.
5. **Lower incisor linear measurement:** Measurment of posterior angle between the long axis of lower incisors and mandidular plane.

Hard Tissue Linear Measurement(Figure 1, A)

1. **Upper Anterior Facial Height (AUFH)**: Plane constructed from Nasion (N) to the Anterior nasal spine ANS).
2. **Lower Anterior Facial Height (ALFH)**: Plane constructed from Anterior nasal spine (ANS) to Menton.

3. **Posterior Facial Height (PFH)**: Plane constructed from Sella (S) the centre of the hypophyseal fossa (sella turcica) to the Gonion (Go).
4. **Position of hyoid bone:** the distance from AH to cervical column measured parallel to FH, the horizontal position of the hyoid bone.

Linear Measurement Of Upper Airway Space And Soft Tissue-(Figure 1 A,B)

1. **Superior posterior airway space (SPAS) -** Measured from a point on posterior outline of the soft palate to the closest point on the pharyngeal wall. This measurement is taken on the anterior half of the soft palate outline.
2. **Middle airway space (MAS)-** Measured from the point of intersection of the posterior border of the tongue and inferior border of the mandible to the closest point on the posterior pharyngeal wall.
3. **Inferior airway space (IAS)-** Measured between the posterior pharyngeal wall and the point of intersection of tongue with hyoid bone i.e V - LPW: the distance from V to LPW, representing the Inferior airway space.
4. **Tongue length (TGL)-** Measured between tip of the tongue and base of the epiglottis Eb, the deepest point of the epiglottis.
5. **Tongue height (TGH**)- The linear distance between a point on the most superior curvature of the tongue dorsum and the base of a line drawn perpendicular to the TF-Eb line.
6. **Soft palate length (PNS-P)-** The linear distance between posterior nasal spine, PNS and P.

Measurement Of Upper Airway And Soft Tissue Area

1. **Nasopharynx (mm^2):** the area outlined by a line between R and PNS, an extension of the palatal plane to the posterior pharyngeal wall, and the posterior pharyngeal wall.
2. **Oropharynx (mm^2):** the area outlined by the inferior border of the nasopharynx, the posterior surface of the soft palate and tongue, a line parallel to the palatal plane through the point Et, and the posterior pharyngeal wall.
3. **Hypopharynx (mm^2):** the area outlined by the inferior border of the oropharynx, the posterior surface of the epiglottis, a line parallel to the palatal plane through the point C4, and the posterior pharyngeal wall.
4. **Tongue (mm^2):** the area outlined by the dorsal configuration of the tongue surface and lines that connect TT, RGN, H, and Eb.
5. **Soft palate (mm^2):** the area confined by the outline of the soft palate that starts and ends at PNS through P.

The morphology of soft palate of all the subjects was examined and traced using 0.5 mm lead pencil and classified into 5 types (Figure 3)

1. Type 1- leaf shape
2. Type 2-Rat tail shape
3. Type 3- S- Shape
4. Type 4- Butt shape
5. Type 5- crook shape

- Manual tracing of hard tissue analysis, upper airway space and soft tissue (soft palate and tongue) of all radiographs was done using 0.5 mm lead pencil on acetate paper**.**

- Area calculation of upper airway and soft tissue (soft palate and tongue) was done with **Image tool 3.00 software** in pixel square which was converted into mm square by multiplying the value with 0.264.
- The measurements recorded in the proforma of Lateral Cephalogram **(Annexure III)** and of Computed Tomograph **(Annexure IV)**

Upper Airway Soft Tissue Volume Calculation (Figure 4)

1. Nasopharynx
2. Oropharynx
3. Hypopharynx
4. Tongue
5. Soft palate.

Soft tissue	**Upper limit**	**Lower limit**
Nasopharynx	Cranial base	Posterior border of the hard palate.
Oropharynx	Posterior border of the hard palate	Tip of the soft palate
Hypopharynx	Tip of the soft palate	Tip of the epiglottis
Tongue	Anterior 2/3rd of tongue	Posterior one third of the tongue behind the plane of the circumvallate papillae.
Soft palate.	Hard palate	Inferior margin hangs loosely into pharynx

The volume was calculated using the 'Paint on slices' tool on the workstation by applying paint on all the slice of the image stack in the axial plane of each upper airway soft tissue.

Then switching to the **'Histogram'** view on the workstation automatically reflects the volume of the sinus in cubic centimeters **(cc).** The entire procedure was repeated for each upper airway soft tissue separately for every patient.

Clinical Assessment: The neck circumference was measured at cricothyroid level with the measuring tape. The patients were divided into three groups based on the Neck Circumference (NC):

Group A: - NC less than equal to 30cm;

Group B: - NC 31 to 34 cm;

Group C: - NC greater than equal to 35 cm.

The population was stratified by Body Mass Index (BMI) using cut off points of-

Group I: - < 23- Lean

Group II: - 23 –35- Normal

Group III: - > 25 - Obese

The study included 45 adult patients, which were equally divided into three different malocclusion groups according to Angle's classification.

The ANB angle, which is most commonly used in the determination of anteroposterior dentofacial discrepancy, was used to classify the subjects according to their skeletal configurations.

The subjects were divided according to the ANB angles:

Class I malocclusion i.e ANB angle between 2-4° (n=15),

Class II malocclusion i.e ANB angle > 4° (n=15)

Class III group≤ 2° (n=15).

Table I. Subject Classification By Malocclusion And Sex

GENDER	Class I ANB 2-4° n=15	Class II ANB >4° n=15	Class III ANB ≤.2⁰ n=15	Total n=45
MALE	9(36%)	4(16%)	12(48%)	25(55.6%)
FEMALE	6(30%)	11(55%)	3(15%)	20(44.4%)

Table 2 shows mean and standard deviation of angular, cephalometric, upper airway and soft tissue space and area variables with p Value for different ANB groups.

	Class 1 ANB 2-4° (n=15)		Class II ANB >4° (n=15)		Class III ANB ≤.2⁰ (n=15)		p Value
	Mean	SD	Mean	SD	Mean	SD	
SNA	83.80	2.37	83.00	3.42	77.47	6.22	0.001
SNB	80.93	2.49	77.13	3.42	82.13	5.60	0.001
ANB	2.93	0.96	6.20	1.74	-4.67	3.54	0.001
UAFH (mm)	51.50	4.03	48.87	4.49	50.67	4.34	0.20
ULFH (mm)	64.70	4.99	62.47	5.69	63.40	5.54	0.70
AFH (mm)	116.20	7.51	111.33	8.58	114.07	8.40	.66
PFH (mm)	82.87	7.35	75.33	5.05	79.13	7.67	0.02
PFH divided AFH	73.83	6.96	68.00	2.78	68.39	6.20	0.01
Maxillary Incisor angulation	60.73	6.63	60.33	6.28	56.07	7.69	0.13
Mandibular incisor	99.93	9.87	104.40	6.27	91.13	10.06	0.001
SPAS	14.07	3.13	12.73	1.67	11.47	1.46	0.01
MAS	13.13	2.20	11.07	2.76	12.13	2.75	0.10
IAS	14.33	2.85	12.67	3.50	13.87	3.80	0.39
Tounge length (mm)	71.07	7.54	70.07	7.06	64.67	10.57	0.10
Tounge height (mm)	28.80	4.96	24.53	4.26	26.13	5.38	0.07
Soft Palate (mm)	33.07	4.79	33.93	5.82	32.60	3.36	0.74
Area in mm square							
Nasopharynx (mm^2)	1198.75	179.77	1110.04	155.62	1412.59	215.80	0.001
Oropharynx (mm^2)	3028.70	665.40	2640.47	467.76	3057.65	323.94	0.04
Hypopharynx (mm^2)	1934.32	419.21	1636.46	507.48	1717.73	295.82	0.14
Soft palate (mm^2)	1297.12	167.76	1242.43	175.80	1326.76	175.86	0.41
Tongue (mm^2)	13124.05	2152.14	10590.03	3334.10	11131.60	4124.38	0.10

Table 3: Comparision Of Level Of Hyoid Bone In Three Different Anb Group.

Level of Hyoid Bone	CLASS I ANB 2-4 °	CLASS II ANB > 4°	CLASS III ANB ≤ 2^0	Total
C3	12	13	12	37
C2	0	0	0	0
C4	1	1	1	3
C2&C3	1	0	2	3
C3 & C4	1	1	0	2
Total	15	15	15	45

Table 4 Comparision Of Facial Height, Soft Tissue Linear Measurements And Upper Airway Space And Area In Different Anb Groups On Lateral Cephalogram

However, difference of remaining variables was statistically insignificant (p>0.05).

	CLASS I MALOCCLUSION ANB 2-4° (n=15)		CLASS II MALOCCLUSION ANB >4° (n=15)		CLASS III MALOCCLUSION ANB ≤ 2^0 **(n=15)**		P Value
	Mean	SD	Mean	SD	Mean	SD	
UAFH (mm)	51.50	4.03	48.87	4.49	50.67	4.34	0.20
ULFH (mm)	64.70	4.99	62.47	5.69	63.40	5.54	0.70
AFH	116.20	7.51	111.33	8.58	114.07	8.40	0.66
PFH (mm)	82.87	7.35	75.33	5.05	79.13	7.67	0.02
PFHdividedAFH	73.83	6.96	68.00	2.78	68.39	6.20	0.01
SPAS	14.07	3.13	12.73	1.67	11.47	1.46	0.01
MAS	13.13	2.20	11.07	2.76	12.13	2.75	0.10
IAS	14.33	2.85	12.67	3.50	13.87	3.80	0.39
Tongue length (mm)	71.07	7.54	70.07	7.06	64.67	10.57	0.10
Tongue height (mm)	28.80	4.96	24.53	4.26	26.13	5.38	0.07
Soft palate length (mm)	33.07	4.79	33.93	5.82	32.60	3.36	0.74
Area in mm square							
Nasopharynx (mm^2)	1198.75	179.77	1110.04	155.62	1412.59	215.80	0.001
Oropharynx (mm^2)	3028.70	665.40	2640.47	467.76	3057.65	323.94	0.04
Hypopharynx (mm^2)	1934.32	419.21	1636.46	507.48	1717.73	295.82	0.14
Soft Palate (mm^2)	1297.12	167.76	1242.43	175.80	1326.76	175.86	0.41
Tongue (mm^2)	13124.05	2152.14	10590.03	3334.10	11131.60	4124.38	0.10

Table 5 shows Cephalometric upper airway space and area in the three ANB groups

	Group 1 ANB 2-4° (n=15)		Group 2 ANB >4° (n=15)		Group 3 ANB ≤.2^0 **(n=15)**		P Value
SPAS	14.07	3.13	12.73	1.67	11.47	1.46	0.01
MAS	13.13	2.20	11.07	2.76	12.13	2.75	0.10
IAS	14.33	2.85	12.67	3.50	13.87	3.80	0.39
Area in mm square							
Nasopharynx (mm^2)	1198.75	179.77	1110.04	155.62	1412.59	215.80	0.001
Oropharynx (mm^2)	3028.70	665.40	2640.47	467.76	3057.65	323.94	0.04
Hypopharynx (mm^2)	1934.32	419.21	1636.46	507.48	1717.73	295.82	0.14

Table 6: comparision of different shapes, distribution and proportion of soft palate morphology according to gender on lateral cephalogram.

Shape	TYPE 1 Leaf	TYPE II Rat tail	TYPE III Butt shape	TYPE IV S shape	TYPE V Crook shape	Total
Male	7(28%)	5(20%)	1(4%)	4(16%)	8(32%)	25(55.65)
Female	7(35%)	6(30%)	1(5%)	1(5%)	5(25%)	20(44.4%)

Chi square =2.03,D.F.= 4, p>0.05 i.e. non significant

Table 7 Distribution And Proportion Of Soft Palate Morphology Types Shows Distribution And Proportion Of Soft Palate Morphology Types.

The leaf shape was found in maximum subjects with percentage of 31.3%, followed by crook shape (28.9%), rat tail (24.4%), S shape (11.1%) and butter shape (4.4%).

	leaf	rat tail	Butt shaped	S shape	Crook
N	14	11	2	5	13
Proportion(%)	31.1	24.4	4.4	11.1	28.9

Table 8 shows upper airway and soft tissue volume data for different ANB group on C.T. However, difference of remaining variables was statistically insignificant.

	Class 1 ANB 2-4° (n=15)		Class II Group 2 ANB >4° (n=15)		Class III Group 3 ANB ≤ 2^0 (n=15)		P Value
	Mean	SD	Mean	SD	Mean	SD	
Nasopharynx (cc)	8.5707	1.83331	7.0853	1.43778	8.5793	1.42023	0.019
Oropharynx (cc)	11.619	2.3758	9.605	2.1546	12.318	1.5585	0.002
Hypopharynx (cc)	9.954	1.87746	7.8767	2.36215	10.9347	1.72117	0.001
Tongue (cc)	30.8247	4.78377	28.5307	5.0554	32.088	4.49768	0.131
Softpalate (cc)	7.556	.60433	7.6047	0.67501	7.850	0.94375	0.526

Table 9 shows the mean, standard deviation of Cephalometric and Computed tomographic (CT) upper airway and soft tissue area and volume of male and female group.

Table 9 the mean and standard deviation of cephalometric and computed tomographic (ct) upper airway and soft tissue area and volume according to gender

		Male n=25(55.6%)		Female n=20(44.4%)		P Value
		Mean	SD	Mean	SD	
Lateral Ceph	Nasopharynx (mm^2)	1333.03	229.70	1124.75	148.84	0.001
	Oropharynx (mm^2)	3035.35	559.27	2750.92	456.14	0.07
	Hypopharynx (mm^2)	1815.63	392.86	1696.85	466.86	0.36
	Soft palate (mm^2)	1345.27	160.19	1218.15	165.30	0.01
	Tongue (mm^2)	13378.50	1627.51	9411.14	3794.60	0.001
CT	Nasopharynx (cc)	8.17	1.64	7.94	1.79	0.65
	Oropharynx (cc)	11.99	2.01	10.17	2.34	0.01
	Hypopharynx (cc)	10.85	1.88	8.01	1.88	0.001
	Tongue (cc)	30.74	4.42	30.16	5.56	0.70
	Soft palate (cc)	7.8548	0.80466	7.4395	.61	0.090

Table 10 shows the means, standard deviation of Cephalometric and Computed Tomographic (CT) upper airway and soft tissue area and volume to the age group.

		18-22 year n=28(62.2%)		23-27 year n=17(37.8%)		p VALUE
		Mean	Std. Deviation	Mean	Std. Deviation	
LC	Nasopharynx (mm^2)	1257.41	240.82	1212.53	190.73	0.52
	Oropharynx (mm^2)	2980.37	501.89	2791.28	568.96	0.25
	Hypopharynx (mm^2)	1738.82	324.64	1802.40	565.33	0.63
	Soft palate (mm^2)	1293.56	181.40	1280.88	162.85	0.82
	Tongue (mm^2)	11454.25	3395.99	11880.37	3524.33	0.69
CT	Nasopharynx (cc)	8.18	1.76	7.88	1.60	0.58
	Oropharynx (cc)	11.13	2.06	11.27	2.78	0.85
	Hypopharynx (cc)	9.52	2.19	9.70	2.66	0.81
	Tongue(cc)	30.90	5.19	29.79	4.46	0.47
	Soft palate (cc)	7.8179	0.72398	7.4271	0.74744	0.99

Table 11 shows age, gender, BMI & NC data of subjects in three different ANB group.

	ANB Group	ANB 2-4		ANB > 4		ANB ≤ 2^0	
		Mean	Std.	Mean	Std.	Mean	Std.
Age	18-22 n=28,%=62.2	20.30	1.83	20.67	1.58	20.22	1.72
	23-27 n= 17,%=37.8	23.20	0.45	23.50	0.55	24.33	1.03
Gender	Male (25,55.6)	2.78	0.97	5.75	1.5	5.08	3.58
	Female(20,44.4)	3.17	0.98	6.36	1.86	3.00	3.46
BMI	less than or equal to 23 n=16, %=35.6	19.59	3.01	19.45	3.27	21.40	1.52
	Between 23-25 n=19,%=42.2	23.56	0.62	23.64	0.64	24.33	0.52
	More than or equal to 25 n=10,%=22.2	29.66	2.74	26.33	0.58	26.75	0.96
NC	Less than equal to 30 n=12, %=26.7	3.40	0.89	5.43	0.79	4.80	4.23
	Between 31-34 n=16, %=35.6	2.40	0.89	7.40	2.3	4.83	3.92
	Greater than equal to 35 n=17, %=37.8	3.0	1.0	6.0	1.73	4.25	2.87

Table 12 shows demographic data of patients depending on BMI with NC, Gender and Age.

BMI Group	GROUP I less than 23 (n=16)		GROUP II 23-25 (n=19)		GROUP III more than 25 (n=10)		p Value
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	
Age,yr	21.05	2.26	21.83	2.04	22.64	1.75	0.12
GENDER Female	1.78	0.97	2.43	0.98	2.22	0.83	p > 0.05
Male	1.85	0.69	2.20	0.45	1.00	0.00	p > 0.05
BMI	19.95	2.85	23.97	0.64	22.70	2.25	0.001
NC	29.38	3.03	32.06	4.12	36.25	1.96	P < 0.001

Group I- **Less than 23** – lean

Group II- **Between 23-25**- Normal

Group III- **More than 25**- Obese

Table 13 shows comparision of Cephalometric upper airway space and area according to three different BMI groups. However, difference of variables was statistically insignificant.

		GROUP I less than 23		GROUP II 23-25		GROUP III more than 25		p Value
	BMI Group	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	
Lat ceph	SPAS	13.32	2.75	11.58	1.83	12.91	1.92	0.13
	MAS	12.27	2.78	12.25	2.22	11.64	3.04	0.801
	IAS	14.36	3.58	13.58	3.26	12.18	2.96	0.224
	Nasopharynx (mm^2)	1209.42	194.86	1280.80	264.33	1258.53	236.41	0.648
	Oropharynx (mm^2)	2991.84	556.34	2751.68	570.55	2761.96	434.26	0.508
	Hypopharynx (mm^2)	1732.17	455.81	1721.01	377.69	1869.80	436.16	0.641

Table 14 shows the means, standard deviation of Cephalometric and Computed tomographic (CT) upper airway and soft tissue area and volume of different BMI group.

		GROUP I less than 23		GROUP II 23-25		GROUP III more than 25		p Value
	BMI Group	Mean	SD	Mean	SD	Mean	SD	
Lat ceph	Nasopharynx (mm^2)	1209.42	194.86	1280.80	264.33	1258.53	236.41	0.648
	Oropharynx (mm^2)	2991.84	556.34	2891.68	570.55	2761.96	434.26	0.508
	Hypopharynx (mm^2)	1732.17	455.81	1721.01	377.69	1869.80	436.16	0.641
	Soft palate (mm^2)	1215.12	161.06	1326.33	178.28	1395.08	126.33	0.01
	Tongue (mm^2)	10019.98	3917.29	12502.50	1663.86	13837.80	1989.18	0.004
CT	Nasopharynx (cc)	8.80	1.44	7.73	1.77	6.97	1.47	0.007
	Oropharynx (cc)	11.65	2.36	10.94	2.75	10.52	1.64	0.402
	Hypopharynx (cc)	8.86	2.02	9.76	2.49	10.86	2.42	0.064
	Tongue (cc)	30.14	6.26	32.23	1.98	32.27	3.73	0.324
	Soft palate (cc)	7.4614	0.69099	7.8108	0.30315	7.9345	1.0818	0.99

Table 15 shows demographic data of patients depending on NC (neck circumference) with BMI, Gender and Age.

NC Group	GROUP A less than equal to 30 (n=12)		GROUP B 31-34 (n=16)		GROUP C more than equal to 35 (n=17)		p Value
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	
Age,yr	21.37	2.42	21.90	2.02	22.25	1.04	0 .55
GENDER Male	2.71	0.73	1.25	0.50	1.43	0.53	p< 0.001
Female	2.00	0.71	1.67	0.52	1.00	0.00	p< 0.001
NC cm	25.15	4.23	32.40	0.84	37.06	2.78	0.001
BMI	20.75	3.21	22.11	3.01	26.31	2.48	P < 0.001

TABLE 16 shows distribution of Cephalometric Upper airway space and area according to three different NC (neck circumfernce) groups. However the differences of variables were found to be statistically insignificant.

NC GROUP	NC	less than equal to 30		31-34		more than equal to 35		p Value
		Mean	SD	Mean	SD	Mean	SD	
Lateral ceph	SPAS	12.48	1.91	13.10	3.73	13.25	2.12	0.652
	MAS	12.15	2.76	12.40	2.67	11.63	2.62	0.83
	IAS	13.81	3.57	13.60	3.78	13.00	2.51	0.844
	Nasopharynx (mm^2)	1297.56	222.72	1125.66	229.16	1191.26	154.73	0.09
	Oropharynx (mm^2)	2997.95	376.96	2821.67	832.54	2717.60	513.15	0.36
	Hypopharynx (mm^2)	1714.75	391.33	1745.36	484.63	1946.98	473.57	0.41

Table 17 shows comparision of Cephalometric and Computed tomographic (C.T) upper airway and volume according to different NC (Neck Circumfernce) group.

Highly significant statistical difference was found for tongue area on lateral cephalogram when compared with NC. (p=0.01). However, the difference of variables was statistically insignificant.

NC GROUP	NC GROUP	less than equal to 30		31-34		more than equal to 35		p Value
		Mean	SD	Mean	SD	Mean	SD	
Lateral ceph	Nasopharynx (mm^2)	1297.56	222.72	1125.66	229.16	1191.26	154.73	0.09
	Oropharynx (mm^2)	2997.95	376.96	2821.67	832.54	2717.60	513.15	0.36
	Hypopharynx (mm^2)	1714.75	391.33	1745.36	484.63	1946.98	473.57	0.41
	Soft palate (mm^2)	1261.39	182.35	1268.61	162.71	1406.37	104.70	0.10
	Tongue (mm^2)	10869.02	3709.32	11025.91	1827.60	14870.32	1730.88	0.01
CT	Nasopharynx (cc)	8.43	1.51	7.93	2.01	7.01	1.60	0.11
	Oropharynx (cc)	11.68	2.16	10.37	3.01	10.51	1.60	0.21
	Hypopharynx (cc)	9.67	2.22	8.93	2.61	10.12	2.56	0.55
	Tongue (cc)	30.06	5.31	32.50	5.02	30.39	2.51	0.33
	Soft palate (cc)	7.49	0.6558	7.811	0.56569	8.1025	1.07399	0.175

Table 18 shows comparison of Lateral Cephalogram volume and C.T area variability along with mean,standard deviation and coefficient of variation.

	CT Volume			**Lateral Cephalogram area**		
	Nasopharynx	**Oropharynx**	**Hypopharynx**	**Nasopharynx**	**Oropharynx**	**Hypopharynx**
Mean	8.07	11.18	9.59	1240.46	2908.94	1762.84
SD	1.69	2.32	2.35	222.03	529.98	426.46
CV(%)	0.210	0.208	0.245	0.179	0.182	0.242

More variability in CT with airway compare to Lateral Cephalogram with airway.

Discussion

The present study included 45 patients, which were equally divided into three different groups according to ANB classification given by i.e Class I malocclusion i.e ANB angle between 2-4° (n=15), Class II malocclusion i.e ANB angle >4°(n=15)and class III group ≤2° (n=15). Total number of male patient in the study were 25 with the distribution of 9(36%), 4(15%) and 12(48%) male patients in each ANB group. Total number of female patient in the study were 20 with distribution of 6(30%), 11(55%) and 3(20%) female patient in each ANB group**. (Table 1)**

Our study revealed that with increase in ANB angle (>4°), there is overall lesser dimension of upper airway area and space and with decrease in ANB angle (≤2°),there is overall larger Nasopharyngeal and oropharyngeal area dimension. There was a positive correlation between SNA, SNB and ANB angle and pharyngeal airway i.e Nasopharynx, Oropharynx and hypopharynx (p=0.001). These results are in accordance to **Ceylon and Otkay**[5] where only Oropharynx has significant relation to ANB angle and in contrary to **El Halan**[4] where Oropharynx area has positive correlation with SNB. The only statistically significant difference for the NP (p=0.001) and OP (p=0.04) area was observed between the all three ANB groups.

The interest is focused on the hard and soft tissues and the structures of pharynx because of the potential relationship between the size and the structure of the upper airway and dentofacial morphology. Similar study was carried out by **Ismail Ceylon (1995)**[5], **YS Lee and JC kim (1995)**[15], **WS Son and YS Choi (1996)**[16], **Kim Yong-Il (2009)**[21], **Hwang Y-I (2008)**[20], **Hong J.S(2010).**[22]

Our finding that larger dimension of soft palate length is in ANB group II were in accordance with **Jena et al.**[32]

Our study revealed that Class II malocclusion group had a narrower upper airway associated with a decreased posterior facial height than the Class I malocclusion group. This was in accordance with **Hong J.S et al (2010)**[22] who measured the pharyngeal airway volumes and areas and compared the volumetric and cross-sectional measurements and cephalometric variables in children with ANB group II, using three dimensional CBCT.

The finding that tongue length was significantly shorter in Class III compared with Class I subjects and the position of the hyoid bone and width of inferior pharyngeal space were correlated with the change in ANB angle was in accordance with **Abu Allhaija E. S. (2005)**[19] who measured the uvulo-glosso-pharyngeal dimensions in subjects with different anteroposterior jaw relationship.

These findings were in agreement with the study conducted by **Abu Allhaija E.S. and Al-Khateeb S. N (2005)**[19] **and Kirjavainen and Kirjavainen,**[33] and **WS Son and YS Choi**[16] where hyoid bone position differed in between the groups.

Our present study compared the craniofacial morphology of upper height of patients by analyzing lateral cephalogram, and its relationship with upper airway, soft palate and tongue space, and airway space and found that with increase in PFH, the tongue area increases which is in accordance with **Hwang Y-I et al (2008)**[20] and with increase in AFH, nasopharyngeal area increases, in accordance with **Kerr**[14] Additional findings in our study were that with increase in PFH, there is increase in airway space i.e SPAS, MAS & IAS and with increase in AFH, there is increase in Oropharynx, soft palate area.

Significant relationships between the pharyngeal structures and both dentofacial and craniofacial structures have been reported and therefore, a mutual interaction is expected to occur between them and hence justifies orthodontic interest.

In the present study upper airway space and area was measured and compared in three different ANB groups and found that there is decrease in MAS, IAS and Upper airway area i.e. nasopharynx, oropharynx & hypopharynx area with increase in ANB angle, there is increase in upper airway space i.e SPAS, MAS & IAS in normal ANB group (2-4°) compared with other two groups. The finding that patients with Class II malocclusion had a narrower oropharynx and hypopharynx spaces than patients with class I malocclusion which is in accordance with findings of **Kirjavainen and Kirjavainen**[33] who conducted a study to find the effects of cervical headgear treatment of Class II division 1 malocclusion on upper airway structures in children. The finding of larger nasopharyngeal area in class III compared with class I and II was in contrary to **YS Lee(1995)** [21] where the nasopharyngeal area of class II and III malocclusion group was smaller than class I.

In our study, the morphology of the soft palate on lateral cephalogram was examined[9] on the basis of the various radiographic appearances and were classified into five types as**:** Type 1: 1eaf-shaped; Type 2: Rat-tail shaped; Type 3: Butt-like; Type 4: S-shaped; Type 5: Crook-shaped. Distribution and proportion of these types are presented in. The leaf shape was found in maximum subjects with percentage of 31.3%, followed by crook shape (28.9%), rat tail (24.4%), S shape (11.1%) and butt shape (4.4%)

The frequency of **leaf shaped** soft palate was in accordance with **You. M et al (2008).**[9] The S-shape, which was described as a **hooked appearance** of the soft palate by **Pepin et al,**[34] was found in 5 (11.1%) cases in our study. **Pepin et al**[30] therefore concluded that hooking of the soft palate in awake patients indicates a high risk for OSAS.

In our study, the **gender difference** existed in the comparison of the proportion of the various types. **Lu et al**[35] showed in their results that the velar length of the velopharyngeal incompetence group was significantly smaller than that in the velopharyngeal closure and normal groups. Therefore, it is a likely hypothesized that velopharyngeal adequacy is strongly dependent on a close coordination of the anatomic parts involved in velopharyngeal closure: the soft palate and the contiguous pharyngeal structures.

Cephalometric radiography is an indispensable imaging technique and able to provide valuable skeletal information for upper airway morphology. However, it provides 2-dimensional representation of a 3-dimensional structure and is unable to provide volumetric data or evaluate important soft tissue structures such as vulopalatal complex and base of the tongue.[36] **Schwab R J (1998)**[37] reported significant correlation between the PAS measured with LCR and the volume of the pharyngeal airway on CT, Lateral Cephalometric radiographs provides no information about the lateral structures and cross-sectional area of the upper airway. Computed tomography carries significant advantages over plain radiographs as it allows better delineation of soft tissue and air, therefore more accurate measurements for upper airway morphology.[63] CT scan is a noninvasive technique that permits a detailed 3D assessment of the entire upper airway and has been validated for quantitative measurements of the pharyngeal sizes.[39]

In our study calculated the mean and the standard deviation for all the dimensions of upper airway and soft tissue volume on Computed Tomograph and found that ANB group II subjects revealed overall lesser dimension of nasopharyngeal, oropharyngeal and hypopharyngeal volume, with decrease in ANB angle there is overall larger oropharyngeal and hypopharyngeal volume dimension and with normal ANB angle there is larger nasopharyngeal volume and smaller nasopharyngeal volume. Our finding that subjects with Class II patterns have a significantly narrower pharyngeal airway than those with Class III is in accordance with **Kim Yong-Il et al (2009)**[21] **and Min Oh. K (2011).**[24]

In our study Pharyngeal Airway Space was larger in group I than group II, indicating that the dimensions of the PAS are affected by different anteroposterior skeletal patterns, this is in accordance with **Alves Jr M et al(2012)** [5]

Ji Kim et al[21] found that the nasal airway volumes of the Class I subjects were greater than the Class II subjects, which is in accordance with the findings in our study.

In our study there was no correlation between the nasopharynx airway area and volume which was in contrary to the results of **Aboudara C (2009)**[11] where a moderately high correlation was found between nasopharynx airway area and volume.

Our results showed that Nasopharyngeal area and Oropharyngeal area (OA) and volume of upper airway i.e Nasopharynx(p=0.019), Oropharynx(p=0.002) and Hypopharynx volume(p=0.001) in Class III malocclusion group were increased, which is in accordance with **Hong J.S et al (2011)**[23]

Currently, the advances in computed tomography (CT) imaging and the three-dimensional technology allow better visualization of the airway and volumetric analysis .[11] Clinicians can more easily perform the volumetric measurements and also calculate the cross-sectional areas of the airway in three planes of space: coronal, sagittal, and axial[37]. The axial plane, which is not visualized on a lateral cephalogram, is the most physiologically relevant plane because it is perpendicular to the airflow.[40,66]

Our study calculated the mean along with the standard deviation for all the dimensions of Upper airway volume and on computed Tomography (C.T) and Lateral Cephalogram of both the gender. We found that the upper airway volume and area in males had overall larger dimensions than in females. These findings are in accordance with **Martin et al**[6]**, WS Son**[16]**,** and **Samman N.**[17]

Our study attempted to correlate the size of the upper airway and soft tissue structures with age. (**Table 10**) The subjects were ranging from **18 to 25 years** of age to ensure that the pharyngeal structures had reached adult size. The area and volume of the upper airway and soft tissue structures in two different age groups were compared i.e. from 18 to 22 yrs and from 23-27 yrs. Our results show that nasopharyngeal size tends to decrease with growing age**. (*p=0.52*)**

Handelman and Osborne[42] and **Tourn**[43] have stated that the nasopharyngeal depth is formed at the early stages of life and then it usually remains the same. **Jeans et al.**[44] have reported that the nasopharyngeal airway area increases rapidly until 13 years of age and after this period, the growth slows down which is in accordance with our study.

In the present study, Neck circumference and BMI was calculated for each subject in three different ANB groups to rule out the relationship of NC, Obesity, craniofacial, upper airway and soft tissue measurements with sleep apnea as mentioned in **Table 11.**

45 subjects were divided into three groups according to BMI i.e less than or equal to 23 (n=16, 35.6%), between 23-23(n=19, 42.2%) and more than or equal to 25(n=10, 22.2%). **Table 12** showed the demographic data based on BMI and found that there was no difference in age between the groups. Similar study was carried out by **Ferguson. K.A (1995)**[26], **Katz I et al**[45]**, Hoffstein V**[46]**, Mayer. P et. al (1996)**[13] where the relationships between obesity, NC, and upper airway morphology and sleep apnea were evaluated.

Ferguson.K.A et al (1995)[27] evaluated the relationships between neck circumference (NC), body mass index, apnea severity, and craniofacial and upper airway soft-tissue measurements from upright lateral cephalometry on patients divided into three different NC groups and found upper airway soft-tissue and craniofacial abnormalities are related to OSA patients.

The NC was correlated with body mass index and it was found that body mass index (BMI) increased progressively from group A to C with variations, which is in accordance with author **Ferguson K.A et al (1995).**[27]

Table 13 compared the Cephalometric upper airway space and soft tissue variables in different BMI groups and found that there is decrease in **SPAS**, **MAS, IAS** with increase in BMI and in patients with BMI <23, there is narrower nasopharynx and hypopharynx area.

The upper airway size was evaluated on lateral cephalogram and C.T and and found that soft palate and tongue size increased with increasing BMI and were different among groups and no relationship was found between upper airway and BMI which is accordance with author **Lowe A. A**[12] **(1995).**

The subjects in our study were also divided into three groups according to NC i.e i) less than or equal to 30 (n=12, 26.7%), ii) between 31 to 34(n=16, 35.65%) and iii) greater than equal to 35(n=17, 37.8%) and the NC was correlated with body mass index and it was found that NC increased progressively from group A to C with increasing BMI and was different among groups.

Tongue cross-sectional area and volume increased as NC increased and were different between groups. Soft palate area and volume increased with increasing NC and were different among groups which were in accordance with **Ferguson K. A.**[27] **(1995).**

Since the soft palate and the tongue are structures composed of soft tissue with no rigid support, they are greatly affected by gravitational forces. Therefore, in CT scans and other examinations performed in the supine position, these structures move further toward the posterior pharyngeal wall, which results in changes in the dimensional measurements of the upper airway space, as demonstrated by **Lowe et al and**[12] **Abramson et al.**[41] Thus, scan results obtained in supine position is recommended for individuals with OSAS.

Cross sectional upper airway measurements of the SPAS, Nasopharynx, and hypopharynx did not relate to NC**.** Our study also concluded that there was reduction in MAS, IAS and oropharyngeal airway with increasing NC.

Table 14 and 17 show relation between BMI, NC, upper airway and soft tissue that with increasing BMI and NC there is increase in soft tissue size. **Ferguson K.A.(1995)**[27] evaluated relationships between neck circumference (NC), body mass, apnea severity, and craniofacial and upper airway soft-tissue measurements from upright lateral cephalometry and found that NC is related to obesity, tongue and soft palate size. Patients with larger NC have larger tongue and soft palate with no difference in the upper airway size and NC which is in accordance with our study.

The variability of measurements of lateral cephalogram and computed tomography was compared in **(Table 18).** The result showed that C.T measurements show more variability than corresponding airway area which is in accordance to **Aboudara *et al.* (2003).**[18] The reliabily of the airway measurements in three dimensional C.T were compared with data obtained with two dimensional cephalograms.

Aboudara et al. (2009)[11] indicated that there is a significant positive relationship between nasopharyngeal airway size on a headfilm and its true volumetric size from a CBCT scan. They concluded that the three-dimensional CBCT scan is a simple and effective method to analyze the airway accurately.

Abramson et al. (2010)[41] correlated the three-dimensional CT findings of airway size and shape with lateral cephalometric measurements. Their results indicated that the three-dimensional CT and lateral cephalometric measurements were reliable and reproducible.

Conclusion

From the results of this study, it can be concluded that there is a significant association between craniofacial morphology and pharyngeal airway sagittal dimension in three different levels i.e Nasopharynx, Oropharynx and Hypopharynx Therefore, both the measurements acquired from lateral cephalogram and C.T are reliable and reproducible but Lateral Cephalometric radiographs provides no information about the volumetric measurements of the upper airway. The results of airway obtained in C.T shows more significant difference and the coefficient of variation percentage showed that CT airway volume shows more variability than corresponding airway area on Lateral Cephalogram.

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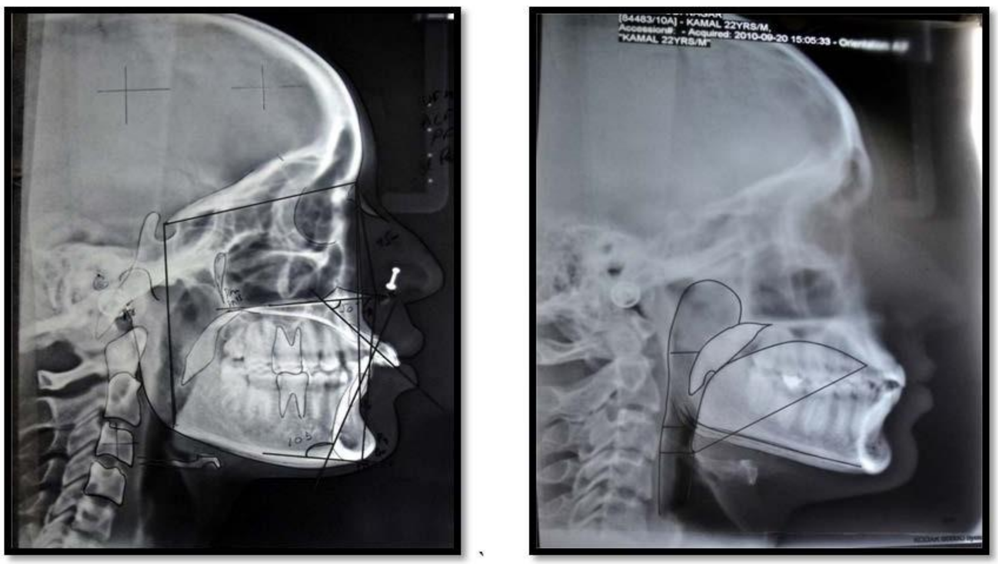
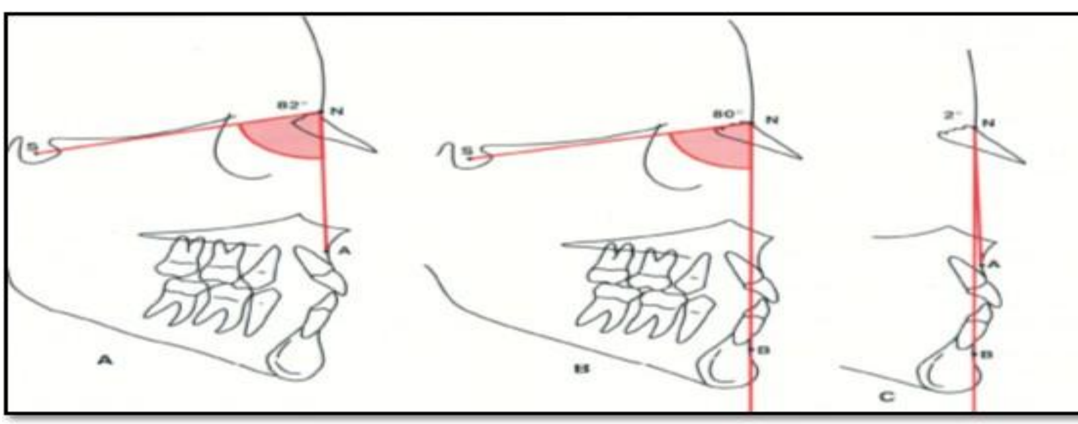
Figure 1: Linear Measurement



A. Hard Tissue B. Airway Space and Soft Tissue

Figure 2: Cephalometric Tracings



A. SNA angle B. SNB angle C. ANB angle

Figure 3: Airway Shapes on Cephalogram

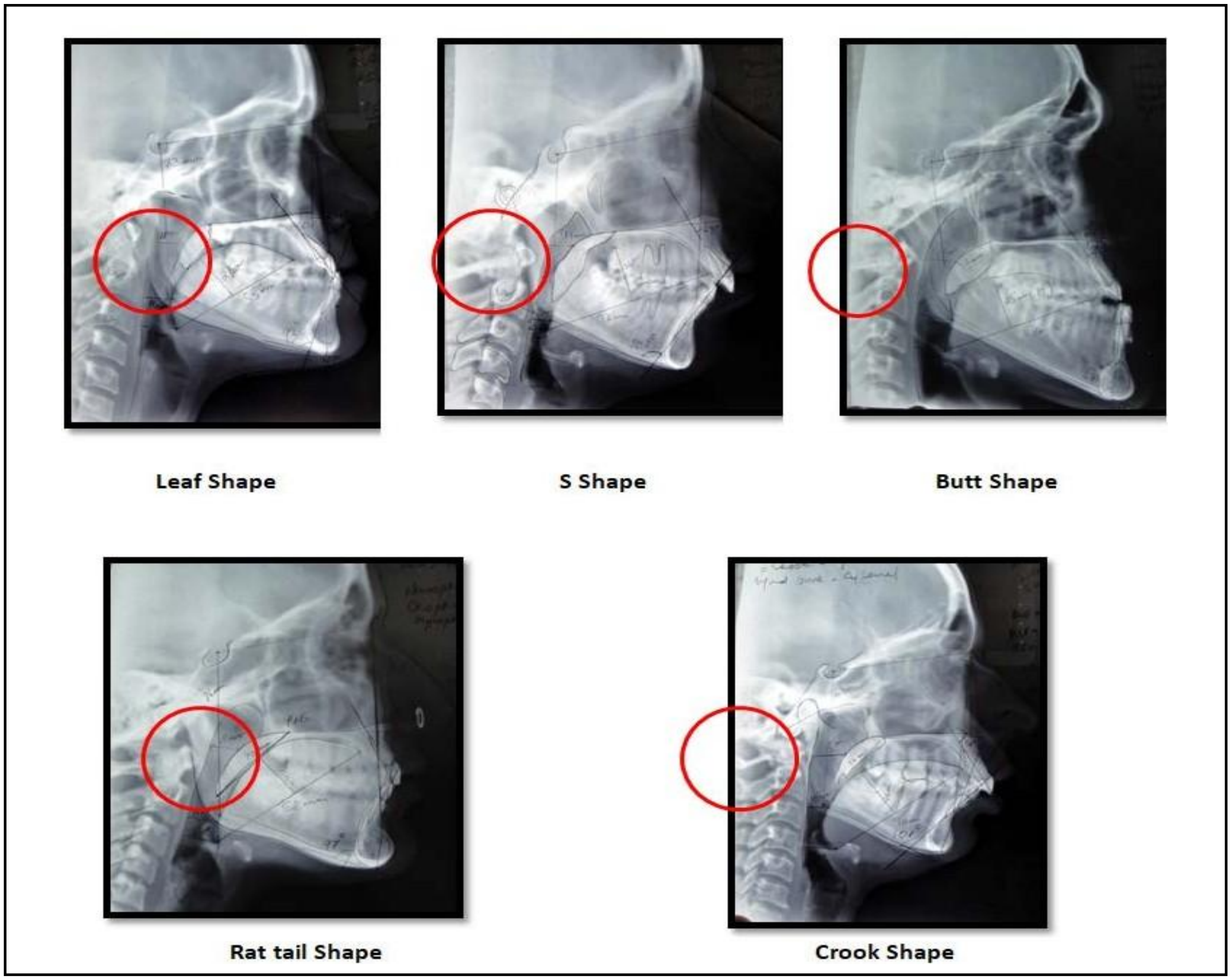


Figure 4: Volume Calculations on CT