PHARYNGEAL AIRWAY ANALYSIS IN RELATION TO POSITION OF HYOID BONE USING LATERAL CEPHALOMETRICS

Dissertation Submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In Partial Fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH IX

ORAL MEDICINE AND RADIOLOGY

MAY 2020

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI

DECLARATION BY THE CANDIDATE

This is to certify the dissertation titled "**PHARYNGEAL AIRWAY ANALYSIS IN RELATION TO POSITION OF HYOID BONE USING LATERAL CEPHALOMETRICS**" is a bonfide and genuine research work carried out by me under the guidance of **Dr.KAILASAM, B.Sc.,M.D.S.,** Professor and Head, Department of Oral Medicine and Radiology, Ragas Dental College and Hospital, Chennai.

G. Jayashree

Dr. G. Jayashree,
Post Graduate Student,
Department of Oral Medicine and Radiology,
Ragas Dental College and Hospital,
Chennai- 600119.

Date: 24.1.2020

Place: Chennai

CERTIFICATE

This is to certify that this dissertation titled "**PHARYNGEAL AIRWAY ANALYSIS IN RELATION TO POSITION OF HYOID BONE USING LATERAL CEPHALOMETRICS**" is a bonafide and genuine research work done by **Dr.G.JAYASHREE** , under my guidance during her postgraduate study period 2017-2020.

This dissertation is submitted to **THE TAMILNADU Dr. M.G.R MEDICAL UNIVERSITY,** in partial fulfilment for the degree of **MASTER OF DENTAL SURGERY, BRANCH IX - Oral Medicine & Radiology.**

It has not been submitted (partial or full) for the award of any other degree or diploma.

Guided by:

Dr. S. Kailasam, B.Sc., M.D.S.,

Professor & Head,

Department of Oral Medicine & Radiology,

Ragas Dental College & Hospital,

Chennai-600119

Dr. S. KAILASAM, B.Sc., M.D.S
PROFESSOR & HEAD
DEPT. OF ORAL MEDICINE & RADIOLOGY
RAGAS DENTAL COLLEGE & HOSPITAL
2/102, East Coast Road,
Uthandi Chennai - 600 119

RAGAS DENTAL COLLEGE Chennai

Co-Guided by:

Dr. R. Sangeetha M.D.S.,

Reader,

Department of Oral Medicine & Radiology,

Ragas Dental College & Hospital,

Chennai-600119

Dr.R.SANGEETHA, M.D.S.,
READER
DEPT. OF ORAL MEDICINE & RADIOLOGY
RAGAS DENTAL COLLEGE & HOSPITAL
UTHANDI, CHENNAI - 600 119.

Dr.N.S.Azhagarasan, M.D.S.,

Principal,

Ragas Dental College and Hospital, Chennai-600119

PRINCIPAL
RAGAS DENTAL COLLEGE AND HOSPITAL
UTHANDI, CHENNAI-600 119.

Date: 24. 1. 2020

Place: Chennai

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI

PLAGIARISM CERTIFICATE

This is to certify that the dissertation titled "**PHARYNGEAL AIRWAY ANALYSIS IN RELATION TO POSITION OF HYOID BONE USING LATERAL CEPHALOMETRICS**" of the candidate **Dr.G. JAYASHREE,** for the award of degree of **MASTER OF DENTAL SURGERY** in **BRANCH IX – ORAL MEDICINE AND RADIOLOGY,**

on verification with the urkund.com website for the purpose of plagiarism check, shows **8 percentage** of plagiarism in the uploaded files containing introduction to conclusion, as per the report generated and is enclosed in Annexure – III.

Date: 24.1.2020

Place: CHENNAI

G. Jayal

Dr. G. Jayashree,
Post Graduate Student,
Dept. of Oral Medicine and Radiology,
Ragas Dental College and Hospital,
Chennai-600119.

Guide Sign & Seal:

S. Kailasam.

Dr. S. Kailasam, B.Sc., MDS.,
Professor and Head,
Dept. of Oral Medicine and Radiology,
Ragas Dental College and Hospital,
Chennai-600119.

Dr. S. KAILASAM, B.Sc., M.D.S
PROFESSOR & HEAD
DEPT. OF ORAL MEDICINE & RADIOLOGY
RAGAS DENTAL COLLEGE & HOSPITAL
2/102, East Coast Road,
Uthandi Chennai - 600 119

ACKNOWLEDGEMENT

Words seem fewer to put across my respectable gratitude to my guide, **Dr. S. Kailasam B.Sc., MDS, Professor and Head,** Department of Oral Medicine and Radiology, Ragas Dental College and Hospital, Chennai, who has been instrumental in shaping my views throughout the completion of my dissertation in all aspects. His enthusiasm and unlimited zeal proved to be a major driving force throughout the dissertation completion. Sir, I solemnly express my deep felt gratitude for your valuable guidance and suggestions, tireless pursuit for perfection, constant support and keen surveillance for the minute details throughout this dissertation.

I take this opportunity to thank**, Dr. N.S. Azhagarasan, M.D.S, Principal,** Ragas Dental College & Hospital and to **Dr. N. R. Krishnaswamy, M.D.S, Vice-principal,** Ragas Dental College and Hospital for their generous support rendered throughout my course.

I thank **Dr. N. Santana, M.D.S, Professor,** Department of oral medicine and radiology, Ragas Dental College, for helping me throughout my study, shaping up my clinical acumen and giving me constant support and encouragement.

I express my deep sense of gratitude to **Dr. R .Sangeetha, M.D.S, Reader,** for her valuable help and who was there at each step guiding me to prepare this dissertation. I am deeply grateful for her detailed and constructive comments, and for her important support throughout this work.

I extend my sincere heartfelt thanks to **Dr. B .Anand, M.D.S, Dr. Massillamani, M.D.S, Dr. Venkatalakshmi Aparna, M.D.S, Dr. R. Malavika, M.D.S, Readers,** Department of Oral Medicine and Radiology, Ragas Dental College, for helping me throughout my study and giving me constant support and encouragement.

I extend my heartfelt thanks to **Dr. I. K. Mammootty, M.D.S, Dr. M. Deivanayagi, M.D.S, Dr. Lalitha M.D.S, Senior lectures,** Department of Oral Medicine and Radiology, Ragas Dental College, for helping me throughout my study and giving me constant support and encouragement.

I extend my gratitude to my seniors **Dr.Geetha**, **Dr.Leena Dandu**, **Dr.Nagaleela Guntuku** for encouraging me and helping me in completing this dissertation. I also thank my colleagues**, Dr.Narmatha, Dr.Ezhil Pallavi, Dr.Sornaa, Dr.RajPrabha, Dr.Soundarya,** and **Dr.Pavana,** for their friendly help, support and cooperation throughout my postgraduate life.

I extent my heartful thanks to my supportive parents **Mrs. S.Sujatha** and **Mr. N.K.Gopinath** and to my brother **G.Pranesh Roy** for their love, understanding, support, encouragement and their prayers throughout these years without which, I would not have reached so far. I would like to express my indebtedness for all the sacrifices they have made to see me succeed in my past, present and all my future endeavours.

I express my love and thanks to my pillars of strength, my friends and well-wishers for extending their support throughout my life, without whom this dissertation would not have been completed.

Last but not the least I thank the God for giving me the strength and stamina in accomplishing this dream into a reality, without whom this work would have been impossible.

LIST OF ABBREVIATIONS

S.NO	ABBREVATIONS	EXPANSION
1	OSA	Obstructive Sleep Apnea
2	C3	Third Cervical vertebrae
3	H	Hyoid bone
4	RGn	Retrognathic point
5	HP	Hyoid Plane
6	PNS	Posterior Nasal Spine
7	PPW	Posterior Pharyngeal wall
8	MPW	Middle Pharyngeal wall
9	LPW	Lower Pharyngeal wall
10	ANS	Anterior Nasal Spine

CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF FIGURES

Introduction

INTRODUCTION

Craniofacial structures and dental malocclusion reflect interplay between a number of factors, including tooth size, arch size and shape, the number and arrangement of teeth, size and relationship of the jaws, and related soft tissues including lips, cheeks, and tongue [(4)]. This harmonious integration of the various components of the craniofacial complex for a balanced facial form is achieved by the orthodontic treatment by assessing these structures prior to the treatment by lateral Cephalogram, a ***golden standard*** diagnostic aid in orthodontics.

Lateral cephalograms also help to understand and anticipate the amount and relative rate of growth in different parts of the face, especially during childhood and adolescence to estimate the growth. This knowledge of growth-related changes in this craniofacial complex is essential in planning orthodontic treatment and to retain the post treatment changes [(21)].

Upper airway space and hyoid bone are one of the important part of craniofacial complex for the growth and development of cranial and facial bones and play an important role in the development of skeletal malocclusion. Nasopharynx, hypopharynx and oropharynx are the three components of pharyngeal airway space, made up of more than twenty muscles and play an important role in breathing and swallowing. Studies have depicted a strong association of dentofacial structures and pharynx. Any variation in oropharyngeal airway space may show its effect on dental or skeleton component, so malocclusion is common in patients with abnormal oropharyngeal airway space [24]. The hyoid bone is the only bone that does not articulate with other bones and provides an attachment for the supra- and infra-hyoid muscles which also forms a part of the oropharyngeal complex. It is connected to the pharynx, mandible and skull by muscles and ligaments, as a result they have clinical implications like obstructive sleep apnea. [27, 38].

In Orthodontics, pharyngeal airway is important to evaluate associated hyoid bone structure, since it is influential in maintaining the size of the upper airway. Changes in the positioning of hyoid bone is always accompanied by changes in positioning of mandible during physiological, surgical and also due to orthodontic treatment and may cause a predisposition for change in the volume of the pharynx. The main areas of changes in nasopharynx, oropharynx and hypopharynx are soft palate, lateral wall of pharynx and base of the tongue respectively, these changes lead to lowered hyoid bone position.

So Careful assessment of pharyngeal airway space in relation to hyoid bone position is necessary in the determination of skeleton malocclusion. This is very useful in patients who are at risk of developing malocclusion. The position of the hyoid bone postoperatively might reflect stretching of the Suprahyoid musculature which could contribute to post treatment relapse in orthodontic patients. Therefore the Cephalometric evaluation of upper airway space and hyoid bone position is of paramount importance in orthodontic treatment planning as both have an effect on the treatment outcome. Thus, an interaction exists between upper airway space and hyoid bone with a significant orthodontic interest [15, 52]. Considering this, the present study was conducted with an aim of correlating the hyoid bone position with the measures of the nasopharynx, oropharynx and hypopharynx using lateral cephalograms.

Aims and Objective

AIMS AND OBJECTIVES

AIM OF THE STUDY:

- The aim of the study is to correlate the pharyngeal airway sub regions with the positioning of the hyoid bone in lateral cephalometric.

OBJECTIVE OF THE STUDY

- To compare the position of the hyoid bone at different levels of pharynx .i.e., nasopharynx, oropharynx and hypopharynx.
- Comparison is done by using various lateral cephalometric variables that define the position of hyoid bone.
- Applying the outcome in elaborating the role of lateral Cephalometrics in determining the position of hyoid bone for diagnosing orthodontic patients.
- The position of hyoid bone tells about the developing malocclusion.

Review of Literature

REVIEW OF LITERATURE

The present study is about correlation of pharyngeal airway to position of hyoid bone using lateral cephalometry. A detailed literature review will highlight the importance of the growth and development of upper airway space along with hyoid bone and the way it relates to the development of malocclusions, which is important for understanding the etiology and treatment of orthodontic problems [2]. The contemporary orthodontics also focuses on achieving ideal health and facial development giving priority to upper airway improvement in addition to improving smile and facial appearance. So the protocol of analyzing the airway during decision-making process in preventive, interceptive, or corrective orthodontics has an impact on the treatment outcome [14]. In present scenario, orthodontic treatment is also an integral part of the interdisciplinary team in the management of upper airway sleep disorders [20]. This study also briefs about various aspects of Pharyngeal airway cephalometric analysis with correlation to hyoid bone in orthodontic treatment planning.

Pharyngeal airway space anatomy:

The organs of the airway / respiratory tract that allow air flow during ventilation from the nares and buccal opening to the blind end of the alveolar sacs, formed by the nasal cavity, pharynx, larynx, trachea and bronchi. Nasopharynx, hypopharynx, and oropharynx are the components of upper airway space from the nasal cavity to pharynx [30].

Nasopharynx (rhino-pharynx) - post-nasal space, divides from the oropharynx by the palate and lining the skull base superiorly.

Oro-pharynx - connects the naso and hypo pharynx. It is the region between the palate and the hyoid bone, anteriorly divided from the oral cavity by the tonsillar arch.

Hypopharynx - connects the oropharynx to the esophagus and the larynx, the region of pharynx below the hyoid bone.

SUBDIVISIONS OF UPPER AIRWAY

Patency of upper airway:

The neural regulation of the upper airway by dilating muscle activities (neural mechanism) and structural properties of the upper airway (anatomic mechanism) are major determinants of upper airway size and patency [(17)].

Nishino et al (1993), Rivilin et al (1997)[18] have explained the neural regulation of upper airway space by stating that there are 20 or more upper airway muscles surrounding the airway that actively constrict and dilate the upper airway lumen. They can be classified into four groups: muscles regulating the position of the soft palate (ala nasi, tensor palatini, and levator palatini), tongue (genioglossus, geniohyoid, hyoglossus, and styloglossus), hyoid apparatus (hyoglossus, genioglossus, digastric, geniohyoid, sternohyoid) and the posterolateral pharyngeal walls (palatoglossus, pharyngeal constrictors). These groups of muscles interact in a complex fashion to determine the patency of the airway. Soft tissue structures that form the walls of the upper airway include the tonsils, soft palate, uvula, tongue and lateral pharyngeal walls. The main craniofacial bony structures that determine the airway size are the mandible and the hyoid bone; these presumably act by providing the anchoring structures to which muscles and soft tissue attach**.**

During inspiration, negative intraluminal pressure pulls three soft tissue elements, the tongue, posterior pharyngeal walls, and soft palate, toward each, thereby reducing the airway lumen in the pharyngeal region. This airway-collapsing action is opposed by pharyngeal dilator muscles. Additionally, activation of the pharyngeal constrictors stiffens the airway walls [30].

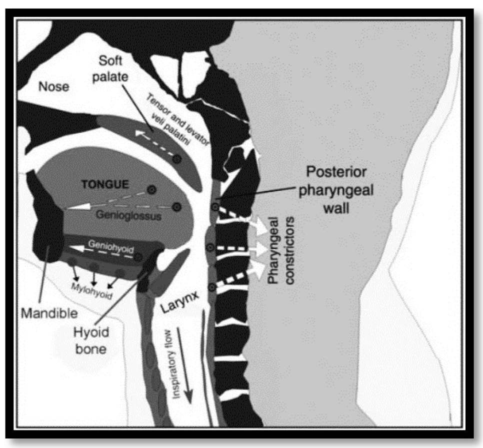


Figure 1. *Schematic representation of a sagittal cross-section through the upper airway*.

Schwab et al (1998)[17] explained that the ability of the upper airway to maintain its patency in the wake state is primarily dependent on the retropalatal oropharynx, as the anterior wall of the oropharynx is composed primarily of the soft palate, tongue and lingual tonsils; and the posterior wall is bounded by a muscular wall made up of the superior, middle and inferior constrictor muscles that lie in front of the cervical spine.

The lateral pharyngeal walls are a complex structure made up of muscles (hypoglossus, styloglossus, stylohyoid, stlylopharyngeus, palatoglossus, palatopharyngeus, and the pharyngeal constrictors), lymphoid tissue and pharyngeal mucosa. This complexity of the interactions between these different muscles makes the oropharynx an extremely difficult structure to evaluate and a potential location to collapse during sleep.

Table 1: Major Orofacial Muscles Whose Contraction Affects the Lumen and Patency of the Upper Airway *(14,17,18)*

Muscle name *(cranial nerve providing motor innervation)*	**Presumed action on upper airway** *(airway-dilating action)*
Alae nasi (VII)	Widens nares
Tensor veli palatini (V)	Moves soft palate up
Levator veli palatini (V)	Moves soft palate up
Genioglossus (XII)	Moves tongue down and anterior
Hyoglossus (XII)	Moves tongue down and posterior
Geniohyoid (XII)	Moves tongue down; hyoid bone up
Pharyngeal constrictors (X)	Stiffen posterior pharyngeal wall
Mylohyoid (V)	Stiffens floor of the mouth

Kuna et al (1999)[16]***, Malhotra et al (2000)***[35] state that the two hypotheses that attempt to explain upper airway collapse are: the neural hypothesis, which implies reduction of the oropharyngeal dilator muscle activity that stiffens the airway and the anatomical theory which explains the collapse through the relationship of bony anatomy and soft tissues relaxation during sleep. Also the deposits of cervical fat may also contribute to the reduction of airway patency.

Relationship between pharyngeal airway and hyoid bone:

The hyoid bone is a horseshoe-shaped bone situated in the anterior midline of the neck between the chin and the thyroid cartilage, which is connected to the pharynx, tongue, mandible and cranium through muscles and ligaments and forms a part of oropharyngeal complex. It consists of five segments, namely, a body, two greater cornua, and two lesser cornua [25].

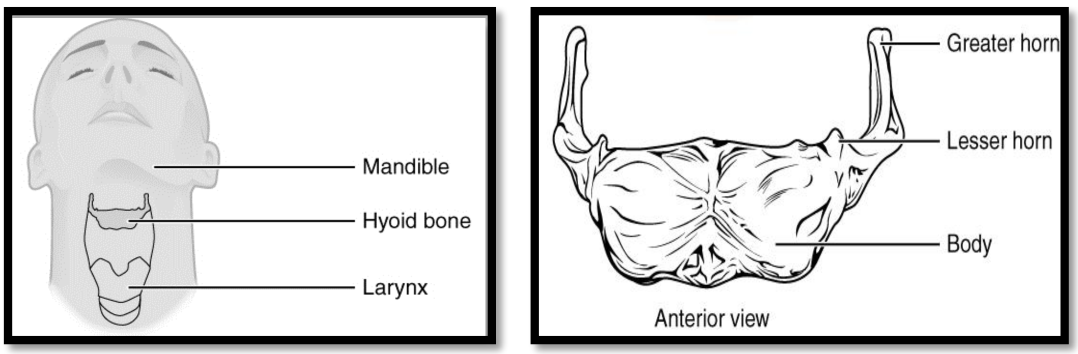


Figure 2 : Anatomy of Hyoid Bone

The hyoid bone position with respect to the cranial base and the mandible determines the tongue posture and function, which plays an important role in maintaining the airway and upright natural head position, so the position of the hyoid bone is influenced by the position of the tongue, thus affecting the pharyngeal airway space, which makes it a good diagnostic guide to malocclusions elicited by destructive oral habits such as atypical deglutition or mouth breathing [35].

Gray H (1954)[52] stated that the hyoid muscles connect the hyoid bone to different structures such as the tongue, the mandible, the base of the skull, the sternum, the scapula, the thyroid cartilage and the pharynx. Because of the complex attachments of the hyoid bone to different structures, changes in the position of those may influence its position in space.

Bench et al (1963)[33] stated that the hyoid bone descends gradually from a position opposite the lower half of the third and the upper half of the fourth cervical vertebra at the age of 3 years to a position opposite the fourth cervical vertebra in adulthood.

Hariston et al (1990)[34]***, Cheeseman (1996) and Kuna (1997)***[40] have studied relationship of muscle attached to hyoid bone and pharyngeal air space and postulated that the anteroposterior dimension and resistance of the hypopharynx are determined both by the activity of genioglossus and the position of the mandible to which it is attached by moving the tongue anteriorly to open up the retroglossal air space. It also plays an important role in narrowing the pharynx and braking airflow during the expiratory phase along with pharyngeal constrictors.

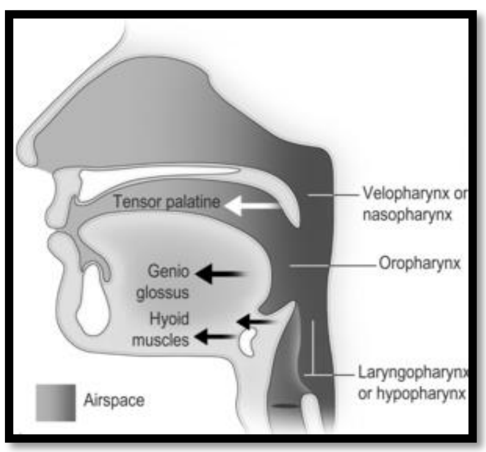


Figure 3 : Influence of hyoid bone on upper airway space

Thurow et al (1995)[17] proposed that the anteroposterior position of the hyoid is maintained by the geniohyoid muscle due to which airway patency was maintained throughout the various movements of the craniofacial complex.

Deegan (1995) and pierce (1995)[49] stated that the epiglottis is suspended at its base by the hyoepiglottic ligament and the hyoid bone. During inspiration, the patency of the retroepiglottic pharynx relies on the activity of the hyoid muscles. The actions of these muscles (the geniohyoid, sternohyoid, and thyrohyoid muscles) bring the hyoid bone to a forward position and stabilize the retroepiglottic pharynx by tensing the hyoepiglottic ligament.

Abu Al Haija and Al Khateeb (2005)[25,27] concluded that the hyoid bone might be regarded as the representative of the postural behavior of the tongue, as the hyoid bone moved forward it would pull the tongue anteriorly, making the genioglossus muscle to generate upper airway dilating forces to maintain upper airway patency at the level of the base of the tongue.

Yassaei, Soroush and Bettagel et al (2008)[43] stated that hyoid bone is positioned more posteriorly and superiorly, which encroaches the airway and the pharyngeal size and has the least amount of displacement in the upward direction. This is also least damaging to the pharyngeal space.

Deljo et al (2012)[12] described muscle attachments of hyoid bone play an important role in the maintenance of the pharyngeal airway, deglutition and phonation. The position of tongue relative to upper and lower jaw is regulated in part by the position of the hyoid bone.

Importance of pharyngeal airway and position of hyoid bone in orthodontics:

The mutual interaction between the pharyngeal structures and the skeletal relationship is a subject of interest for the orthodontists. they believe that evaluation of upper airway structures should be an integral part of orthodontic diagnosis and treatment planning [(2)].

The pharyngeal airway is a multifunctional structure that is responsible for many physiological functions like swallowing, vocalization and breathing and it also play a significant role in the development of the craniofacial complex. Any alteration in the pharyngeal space in relation to position of hyoid bone may result in abnormal physiological functions resulting in malocclusions.so these parameters are important in the decision making process of orthodontics [(10,14,20)].

Certain Orthodontic procedures used to modify the growth pattern in a feasible measure. So to gain the stability of any orthodontic correction, the treatment should be completed during early adolescence, where the associated oropharyngeal structures like upper airway space and hyoid bone position have attained their maximum development and after this period there is no potential for further growth. if this parameter is not taken into consideration during the orthodontic treatment planning, the remaining growth potential of orofacial structures like upper airway space and hyoid bone may undo the treatment outcome after the completion of orthodontic treatment [(19,52)].

Role in obstructive sleep apnea:

Significant component of craniofacial development occurs in the first 4 years of life. Ninety percent of craniofacial development is complete by the age of 12 years; therefore, it can be concluded that morphometric features including the upper airway space and position of hyoid bone, that put adults at risk of obstructive sleep apnea (OSA) are probably present as early as 12 years of age. Hence, addressing these features at an early age may significantly reduce OSA or prevent the same in the future [(20)].

There were two conflicting opinions regarding the relationship between pharyngeal airway and craniofacial growth: one opinion was breathing pattern as an etiological factor for vertical malocclusion and the other opinion was that the vertical malocclusions have an inherited pattern and oropharyngeal airway patency acts as an aggravating factor for vertical growth [(33)].

Scammon et al (1930)[19] concluded that the nasopharyngeal airway is mainly influenced by the adenoids, which are known to follow the lymphoid growth curve. They increase rapidly from infancy, reach a peak before adolescence, and then gradually decrease to their adult sizes.

Moss ML (1969)[14] studied the role of functional matrices in facial growth and concluded that nasal breathing allows proper growth and development of craniofacial and dentofacial complex, based on the principle that normal nasal respiratory activity influences the development of craniofacial structures, favoring their harmonious growth and development by adequately interacting with mastication and swallowing and other components of the head and neck region.

Handelman CS, Osborne G (1976)[14] reviewed the anteroposterior development of nasopharynx and reported that it attains stabilization during early infancy and the two phenomena make the bony nasopharyngeal height increase about 38% are downward movement of palate and the spheno-occipital synchondrosis in a vertical direction. This contributes to the increase in nasopharyngeal capacity, which continues until maturity and parallels sexually determined growth of the skeleton (in boys until 18 years of age or later, in girls until about 13 years of age).

Subtelny et al (1980) and Tomes (1984)[42] found that in females, nasopharyngeal airway space remains stable starting from infancy till they develop maturity, whereas in males, variation may be seen in different age groups and hypothesized that maxillary constriction could be caused by enlarged adenoid of the pharynx that in turn makes the lip incompetent and a lower tongue position to maintain the permeability of the airway.

These inference tells that growth of craniofacial and upper airway reaches their maximum growth before adolescence, which plays key role in deciding the timing of orthodontic treatment.

Lyberg et al (1989)[51] concluded that the position of the hyoid bone may be important consideration for obstructive sleep apnea because it anchors the musculature of the tongue. When this bone is low, the tongue positioned further back, reducing airway potency. It has also been shown that, in OSA patients hyoid bone located in a lower position, in relation to different skeletal structures when compared with controls.

Tourne et al (1991)[4] observed the growth pattern of pharynx and summarized that the growth pattern of pharynx is in vertical direction, dictated by the amount and direction of growth at the spheno-occipital synchondrosis and the cervical vertebrae, so the adult nasopharyngeal depth dimensions are established early in life. Whereas at the oropharyngeal level there is stability in growth pattern, which is obtained by the constant position of the hyoid bone relative to the cervical column. So they infer that the functional adaptation of hyoid position in relative to the mandible is made to secure a relatively constant anteroposterior diameter, as it influences the existing craniofacial growth pattern.

Batool et al (2010)[42] stated narrow pharyngeal airway space is one of the predisposing factors for mouth breathing and obstructive sleep apnea. Posterior airway space of less than 10 mm on cephalometric radiography has been suggested as one of the main indications for surgical treatment of OSA. Many studies in the literature like ***Angle, Harvo, Linder-Aronsonand*** and others have demonstrated that airway obstruction can determine the abnormal development of dentofacial growth pattern.

Harari et al (2012)[49] concluded that naso-respiratory obstruction with mouth breathing during critical growth periods in children has a higher tendency for clockwise rotation of the growing mandible, with a disproportionate increase in anterior lower vertical face height and decreased posterior facial height. Such increases in anterior lower vertical face height are often associated with retrognathia and open bite.

Park et al (2014)[48] found that the relative growth and size of the soft tissues surrounding craniofacial skeletal structures determine the size of the pharyngeal space. In vertical growth pattern individuals (lower anterior facial height is increased), the depth of the nasopharynx increases as its posterior wall becomes narrower. If the upper airway becomes narrower, in some cases the air flow resistance may increase, which may also increase the risk of snoring and, in severe cases, lead to obstructive sleep apnea.

Machado & Crespo (2012)[24] described that the lower airway in patients with atypical swallowing, possibly causing changes in tongue posture which leads to change in the position of the hyoid bone, which also in turn influences the facial growth.

Neelapu et al (2017)[33] conducted a systematic review of relationship craniofacial and upper airway morphology in OSA patients and their important finding was a significant decrease in pharyngeal space in OSA patients. Pharyngeal airway space was influenced by surrounded skeletal and soft tissue structures. The decreased pharyngeal airway space may be due to the encroachment and position of other structures namely tongue, soft palate, maxilla, and mandible. These significances tell the importance of upper airway structures in orthodontic treatment planning with habits.

The hyoid bone position in mouth breathers and tongue-thrusters:

Bibby (1984)[51] assessed the hyoid bone position among mouth breathers and tongue-thrusters found that it had a very constant resting position which is not permanently affected by habitual tongue-thrusting or mouth breathing so it could be used as a reference landmark in cephalometric analysis for orthodontic treatment purposes.

Adamidis IP, Spyropoulos MN (1992)[43] showed that mouth breathing was found to affect mandibular position, as well as hyoid bone position and orientation, because of the role played by the suprahyoid muscles in the establishment of a growth direction of the mandible and also influencing the position of hyoid bone.

Ferraz et al (2007)[23, 26] assessed cephalometrically the hyoid bone position in relation to the respiratory pattern. The study concluded that no statistical significant differences in the mandible and hyoid bone position and the respiratory pattern so the hyoid bone kept a stable position and it did not depend on the respiratory pattern

These inferences show that position of hyoid bone can be used as guide for these habits. After orthodontic treatment is completed, there is danger of relapse due to the persistence of either of these habits. So it is necessary to correct the habit as well as correcting the malocclusion, then the hyoid bone may shift its position and the orthodontist will be able to rule out the possibility of relapse due to the habit and will not have to take elaborate precautions to retain the corrected occlusion [22,32,43].

Role in skeletal malocclusions:

Kuroda et al (1966)[26] studied the relationship between the hyoid bone, skull and mandible by using lateral cephalograms. The results showed difference in the hyoid bone position in relation to the anterior cranial base. The body of the hyoid bone located backward in Class II samples and forward in Class III samples in comparison with the control group,

Grant (1998)[51] studied the position of the hyoid bone in class I, II and III malocclusions. He concluded that the hyoid bone position is constant in all three classes and that the position of the hyoid bone is determined by the musculature and not by the occlusion of the teeth.

Sahin Saglam et al (2006)[29] concluded that the hyoid bone position is superior and posterior in females. The hyoid bone was placed inferior in males compared to females for all subjects in three classes of skeletal pattern.

Aboudara et al (2009)[45] studied the upper airway space in two dimensional view and concluded that in both the skeletal malocclusions, vertical growers showed a significant decrease in the airway size than the horizontal and normal growers, indicating that growth pattern affect the upper-airway size. There is no statistical significance between the lower airway and craniofacial growth pattern.

Sumanth et al (2014)[23] concluded that a positive correlation was found between the lower airway and horizontal distance from the hyoid bone to the retrognathion in class I skeletal pattern with average growth pattern. However, there were no correlation found in the horizontal and vertical position of the hyoid bone in class II and III skeletal pattern with normal growth pattern. The hyoid bone maintains a relatively constant position anteroposteriorly in class I, II, and III subjects with average growth pattern. It does not exhibit any significant rotation in subjects with average growth pattern.

Ameryi et al (2014)[22] assessed the relationship between different skeletal patterns and the hyoid bone and allowed to correlate the hyoid bone position to other craniofacial parameters. The study was undertaken to evaluate the changes in the position of the hyoid bone which might induce changes in the position of certain dentofacial structures and it could be instrumental in the establishment of specific structural elements of the jaws and occlusion of teeth which is of great interest to the orthodontists. The results revealed that a significant difference existed among the control group (Class I) and the study groups (Class II and Class III) in both sagittal and vertical planes, which was consistent with ***(Adamidis and Spyropoulos, 1992)*** who reported a significant difference in the position of the hyoid bone between Class I and Class III malocclusions as the hyoid bone laid more anteriorly in Class III than in Class I. This finding could be attributed to the muscular attachment to the hyoid bone and the mandible, so it is moving backward and forward following the mandibular movement in the sagittal plane.

Jaipal Singh Tarkar et al (2015)[21] concluded that the upper oropharyngeal width is seen to be narrower in subjects with vertical growth pattern. The hyoid bone was more inferiorly and posteriorly positioned in subjects with horizontal growth pattern. Variations are seen in upper and lower oropharyngeal widths, posture of the tongue and hyoid bone position in all the growth patterns.

Gabrielli et al (2016)[16] evaluated upper airway space with the help of lateral cephalogram in patients with Class III malocclusion. The study comprised of ten adults in the age range of 26–55 years. The authors concluded that airway may not be affected by slight maxillary or mandibular advancement. Hence, careful airway assessment is important in cases suspecting of malocclusion.

Impact of different orthodontic treatment modalities on airway:

Impact of orthognathic surgery:

Takagi et al (1967)[44] Studied hyoid bone position following surgical correction of mandibular prognathism, only minimal changes in the anteroposterior relation of the hyoid bone to the cervical vertebra were demonstrated.

Schendel SA, Epker BN. (1980)[52] alterations in cranium position may produce changes in regulation of neuromuscular activity, altering muscular tone, which may indirectly affect the position and/or function of cervical spine, hyoid bone, hypolaryngeal system and tongue. When all the above factors are activated after surgical mandibular advancement and act in concert, this may produce mandibular instability, relapse, and as a result certain degree of disturbed head balance may be seen.

Athanasiou et al (1991)[2] reported that the hyoid bone showed a more vertical movement pattern because the patients had raised their heads after surgical correction of the prognathism. They suggest that the constant distance between the hyoid bone and the cervical column and the significant changes of the hyoid bone position with the maxilla and the mandible were mainly the results of postural alterations.

Gu et al (2000)[38] postulated that postoperative hyoid position after mandibular setback surgery may decrease the length and tension of the suprahyoid musculature, resulting in an anteriorly directed skeletal relapse pattern to return the muscles to their original resting tension, which imparts the importance of hyoid bone position in orthodontic treatment planning.

Studies like ***Schendel et al (1980)***[52]***, Soonshin Hwang et al (2010)***[44]***, Ruchengiz Efendiyevaa et al (2014)***[36] has shown that there are changes in the position of the hyoid bone and in pharyngeal size in connection with mandibular advancement surgeries. A surgical mandibular advancement leads to change in length and tension of the related musculature i.e. the supra- and infra- hyoid, the neck extensor, and the cervical fasciae.

Impact of functional appliance:

Jan H. (1999)[19] conducted a study to depict the effect of functional appliance treatment on the position of hyoid bone and he postulated that If the hyoid bone is in the same position after functional appliance treatment then the soft tissues must still be in the same balanced rest position, thus reducing the chances of relapse due to soft tissue forces. However, difference observed in the position of hyoid bone beyond its normal range increases the chances of skeletal relapse are limited. Therefore, the by the steepness of the lower margin of the mandible, Position of hyoid bone can be used as a good indicator in a brachyfacial person who has a hyoid predict relapse tendencies.

Farhana et al (2010)[51] studied the Change in the position of hyoid bone with functional appliance treatment and observed that there was no statistically significant change in the position of hyoid bone with functional appliance treatment.

Ulusoy et al (2014) and Aksu et al (2017)[4] retrospectively studied the effects of activator on nasopharynx, oropharynx and hypopharynx. Earlier study found that the nasopharyngeal area of the treatment group improved significantly compared to pre-treatment value. However, when compared with control, the improvement was not significant. Aksu et al found significant improvement of oropharyngeal airway after activator treatment. However, the contribution to oropharyngeal airway improvement was seen only at the level of MPS. They also concluded that no significant improvement in hypopharynx.

Impact of Retraction Orthodontics:

Wang Q et al (2012)[53] studied Changes of pharyngeal airway size and hyoid bone position following orthodontic treatment of Class I bimaxillary protrusion and postulated that the pharyngeal airway size became narrower after the treatment. Extraction of four premolars with retraction of incisors did affect velopharyngeal, glossopharyngeal, hypopharyngeal, and hyoid position in bimaxillary protrusive adult patients.

Nuvusetty et al (2016)[35] concluded that there was no significant change in the nasopharyngeal airway size following the retraction of incisors after the extraction of all first premolars. There was significant narrowing of pharyngeal airway size behind the soft palate (velopharynx) and highly significant reduction in the pharyngeal airway size behind uvula, tongue (glossopharynx), and at base of the tongue (hypopharynx) following the retraction of incisors after the extraction of all first premolars However, Upper and lower first premolar extraction for the treatment of bimaxillary dentoalveolar protrusion does affect the upper airway dimensions. The respiratory form and size of the pharyngeal airway should be taken into consideration, especially when extraction of four premolars and maximal retraction of anterior teeth are planned.

Cephalometric analysis of pharyngeal airway and hyoid bone:

Cephalometric is an important tool in orthodontic diagnosis, treatment planning, evaluation of treatment results and prediction of growth. Cephalometry provides information on the anteroposterior pharyngeal dimensions, but not on the lateral dimensions [(1)].

The image quality of a cephalograms scanned at resolution of 300 dpi is sufficient for clinical comparison to original analogue cephalometrics [(9)].

Holmberg et al (1977) stated Cephalometric evaluation of the pharyngeal airway has been reported to provide a high correlation**.** Precautions were taken to include radiographs of adequate quality and resolution exposure, and all radiographs were taken in reproducible and unstrained position of the head since difference in head position may interfere with our outcome [(5)].

Landmarks and measurements

Brader and Wildman (1961)[11] studied the cephalometric appraisal of pharyngeal structures in relation to cranial base and formulated the boundary for nasopharynx as:

a. Line from posterior nasal spine to the point of posterior pharyngeal wall interaction.
b. A line extending from PNS superiorly and posteriorly to point Sella
c. A line extending from PPWI, superiorly and anteriorly, following the outline of posterior wall of pharynx to the point of intersection with PNS – Sella line (I).

Based on these reference points ***Mergen and Jacobs (1970)***[12] studied the size of nasopharynx in normal occlusion and class 2 malocclusion and concluded that there is no significant inter relationship between nasopharyngeal morphology and skeletal characteristics.

***Lyberg* et al *(1989*)**[24] analyzed the pharyngeal morphology in obstructive sleep apnea patients using the following cephalometric reference points:

Upper pharyngeal wall	Point of intersection of the line perpendicular to the posterior pharyngeal wall from the PNS.
Middle pharyngeal wall	Intersection of the perpendicular line from tip of the uvula to the posterior pharyngeal wall
Lower pharyngeal wall	Intersection of the perpendicular line from vallecula (intersection of epiglottis and base of the tongue) to the posterior pharyngeal wall.

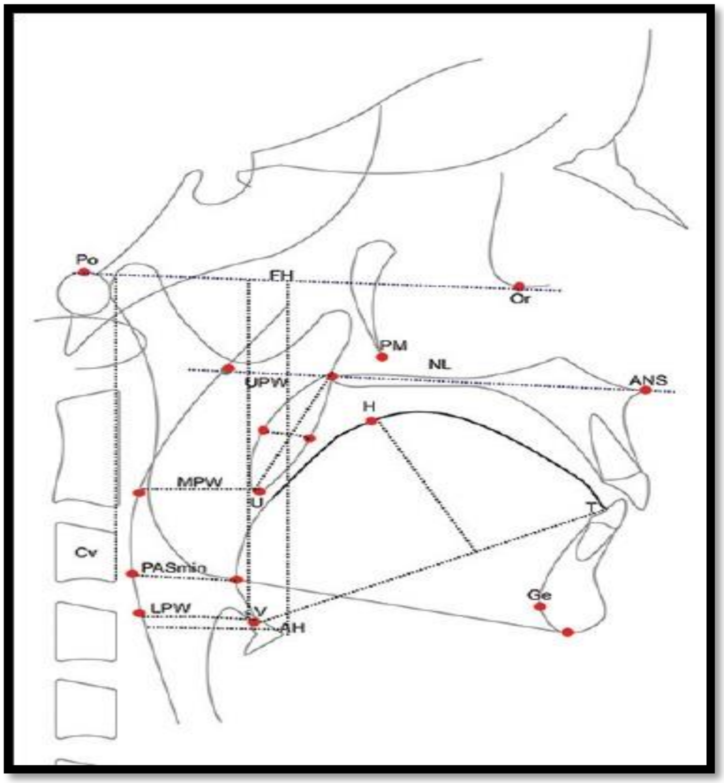


Figure 4: Diagrammatic Representation of the Pharyngeal Space

Many studies like ***Farole et al (1990), Tangugsorn et al (1995), Diphthi et al (2010)*** studied the upper pharyngeal space based on ***Lyberg et al*** specifications and found that there is sexual dimorphism in middle pharyngeal wall variable; reported a magnification of 6% approximately (23,25,27).

Miles et al (1998)[31] meta-analysis of cephalometric studies showed the most relevant variables that may be associated with the development and severity of OSAS: the angle between the anterior cranial base and the maxilla (SNA), the angle between the anterior cranial base and the mandible (SNB), the posterior airway space (PAS), the length of soft palate (PNS-P), and the distance from the hyoid bone to the mandibular plane (MP-H)

,This significance makes cephalometric analysis of upper airway as one of the important diagnostic aid in orthodontics [(11)].

The precise measurement of the hyoid bone position by cephalometric means is considered difficult. Previous investigators have found that the hyoid bone has a highly variable position not only from person to person, but also at different time intervals in the same person. Such variability in results could be attributed to the fact that most analysis has employed cranial structures to define the plane from which the hyoid bone position is measured [(5)]

Rocabado's hyoid triangle is the only cephalometric parameter that can be used to assess the effects of orthodontic treatment of tongue posture [(24)].

Tallgren and Solow et al (1997)[25] have suggested that the position of the hyoid bone might be influenced by two postural systems: change in the mandibular position and changes in the cervical inclination as well as in the craniocervical angulation. Vertical changes in the position of the hyoid bone in relation to the upper face followed the pattern of increase or decrease of the mandibular inclination, whereas the horizontal changes followed mainly the changes in both cervical inclination and craniocervical angulation.

Adamidis et al (1993)[36] stated that the inclination of the hyoid axis was assessed in relation to Frankfurt horizontal plane. The hyoid axis angle was more oblique in hyper divergent pattern, whereas in normo divergent patterns, it was less oblique. This inference shows that the axial inclination of the hyoid followed the pattern of craniofacial divergence

A cephalometric parameter proposed by Bibby and Preston and Rocabado for evaluating the position of the hyoid bone from the mandible and the cervical spine, is based on a triangle constructed by joining the following anatomical points (6):

- *H-point*: the upper edge of the frontal area hyoid body;
- *The retrognathic (RGN) point*: the posterior-lower point of the mandibular symphysis;
- *The VC3ai poin*t: the anterior-lower point of the body of the third cervical vertebra (C3).

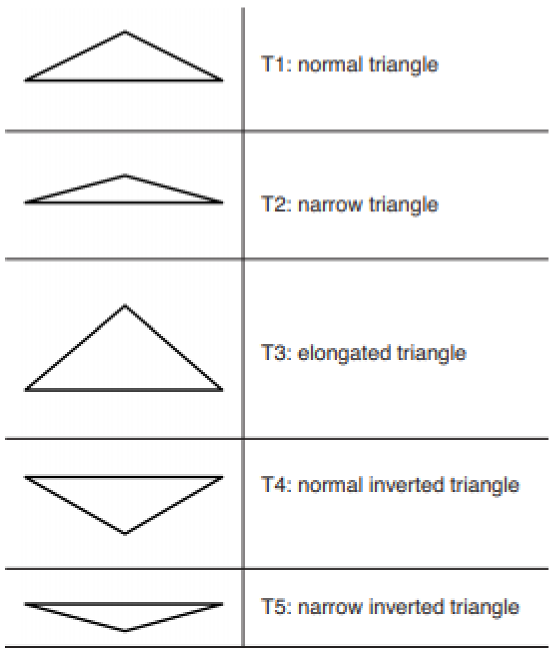


Figure 5: Classification of the Hyoid Triangle

Trenouth and Timms (1999)[32] described a positive correlation between the length of the mandible with the distance between C3 cervical vertebrae and hyoid bone, this inference is due to influence of mandible and associated musculature in changing the position of hyoid bone.

Kollias et al (1999)[31] investigated alterations in craniocervical morphology and the hyoid bone position in different age groups using three series of cephalograms with 10 years interval between each series for each patient (males and females). The mean age of patients was 22 years at the initial evaluation. The results showed that in the males, the descending of the hyoid bone was found to follow a gradual pattern when this bone was related to the sella, Frankfort horizontal plane and the 3rd cervical vertebrae after 20 years and in the female group, statistically significant difference was observed only in the horizontal position of the hyoid bone.

Eung-Kwon et al (2011)[39] observed H-RGN values were significantly higher in short face subjects when compared with vertical and average face subjects. According to which brachyfacial person has a hyoid bone position closer to the mandibular plane and more posteriorly located— i.e. toward the cervical vertebrae

Silva VG et al (2013)[25] stated that attention should be given to the increased distance from the hyoid bone (MP-H), as the muscles of the tongue are partially anchored to the hyoid bone and their height can influence the relationship of soft tissues in the oropharynx. In our series, the analyzed cephalometric variables were SNA, SNB, PAS, PNS-U and MP-H. The values of the SNA, SNB, PAS and PNS-U showed no significant correlation with AHI. In agreement with the studies mentioned above, in our study the only variable that correlated with OSAS severity was MP-H. However, measured values of MP-H in the literature exhibit some variability perhaps reflecting an imbalance between the action of the supra-hyoid and infra-hyoid muscles and the amount of cervical fat deposition.

Antoine Darazane et al (2016)[3] investigated the sagittal cephalometric craniofacial Characteristics of young adult Lebanese subjects. Sexual dimorphism was demonstrated for Co-A and Co-Gn but the remaining variables — both linear (A-N perp to FH (AA')) and angular (ANB, SNA, SNB) — defining the sagittal antero-posterior position of the jaws did not show any statistically significant differences between males and females. There were no significant differences in the values of the facial axis (Pt-Gn/N-Ba) between genders in all 3 classes. When Classes I and II were compared regardless of gender, only two angular variables were significantly different (Pt-Gn/N-Ba and ANB).

Reliability of cephalometric:

Cephalometric was introduced to orthodontics by (Broadbent BH, 1931) as a complement to craniofacial analysis and got wider acceptance in the last twenty years. The soft tissue landmarks in lateral cephalometric are influenced by the superposition of all the structures present in the same plane, which makes some of the landmarks difficult to accurately and reliably identify. It also provides a static assessment of the upper airway in a non-supine subject, with exposure to ionizing radiation.

Bibby and Preston (1981), Michael and Donald (1999) and Maria et al, (2006)[26] mentioned that the importance of the hyoid bone lied in its unique anatomic relationships. They remarked on the great variability of the hyoid position on even slight movement of the head. They determined the position of the hyoid bone by using the cervical vertebra and the mandible as the reference landmarks. They concluded that changes in the anteroposterior head posture and mandibular inclination can affect the hyoid bone position.

Baumrind and Frantz (2001)[5] stated that some cephalometric landmarks can be located with more precision than others, depending on the radiographic complex of the region. The distribution of errors for many landmarks is systematic and follows a typical pattern (non-circular envelop) making the landmarks more reliable in either horizontal or vertical plane depending on the topographic orientation on the anatomic structures along which they are defined.

Agarwal et al (2015)[25] observed direct digitization was slightly more reproducible than the other two methods for most measurements. CADCAS was slightly unreliable with linear measurements involving bilateral structures such as Gonion and Articulae. It can also reduce the time required for making cephalometric measurements. Scanning of cephalometric radiograph at a resolution of 300 dpi is sufficient for clinical purposes and comparable with analog cephalometric radiograph. There is an appreciable amount of error in taking cephalometric measurement from radiographs whichever method is chosen.

Barrera et al (2017)[33] anatomically measured upper airway structures in obstructive sleep apnea patients and they concluded that linear measurements about the airway dimensions nasal PAS, occlusal PAS and mandibular PAS diameter are statistically significant, which infers that cephalometric linear measurements are reliable in diagnosis of obstructive sleep apnea patients.

The contribution of this study was to present the use of a cephalometric analysis, commonly used in orthodontics, with the aim of identifying anatomical changes in the upper airways, which may predispose to respiratory disorders.

Cephalometric analysis has been shown to be an important instrument in the multidisciplinary field for evaluating the upper airways because it is easily accessible and low cost, highly reproducible, and the individual is submitted to a low dose of radiation.

In recent years, many studies have been done concluding that variation in skeletal pattern could predispose to upper airway obstruction. So, cephalometric analysis of upper airway in relation to hyoid bone position can be used in assessment of risk of skeletal malocclusion, which are included in the orthodontic diagnosis and treatment planning. Cephalometric also enables analysis of dental and skeletal anomalies as well as soft tissue structures and form, which is relatively a non-expensive method and gives the morphometric assessment in defined terms of depth and height in the median sagittal plane The use of lateral cephalometric radiographs to evaluate the upper airway is somewhat limited because it provides only 2-dimensional images of the nasopharynx, which consists of complex 3-dimensional anatomic structures.

Materials and Methods

MATERIALS AND METHODS

This is a hospital based study designed to correlate the pharyngeal airway sub regions with the positioning of the hyoid bone.

TYPE OF STUDY

Retrospective study

STUDY PERIOD

The study was done from February 2019 to august 2019.

PLACE OF THE STUDY

- This study was carried out in Department of Oral medicine and Radiology, Ragas dental college and hospital.

STUDY POPULATION

- The study population comprised of 30 lateral cephalometric images of patients present in the department of Oral Radiology, Ragas Dental College and Hospital.

ETHICAL APPROVAL

Ethical clearance was obtained from the Institutional Review Board of Ragas Dental College and Hospital.

SELECTION CRITERIA

INCLUSION CRITERIA

- Patients aged 20 to 40 years old.
- Radiographs of good quality without any errors and distortion.

EXCLUSION CRITERIA

- Patients with a history of surgery and respiratory pathology in the pharyngeal airway and in the hyoid bone were excluded.

METHODOLOGY

Armamentarium required:

The cephalometric device with 20mAs and 75 kvp exposure factors and 1.2 acquisition time.

Lateral cephalometric images of the same patients aged 20 to 40 years old. The images included the entire pharyngeal airway (nasion to fourth cervical vertebra) and had good quality and sharpness in the region of the airway and of the hyoid bone. The images were selected from an archive of images of the Oral Radiology Department. All images were obtained with the Frankfurt horizontal plane parallel to the floor, with the mid sagittal plane perpendicular to the ground and in centric occlusion.

The limits for the segmentation of the airway were determined according to Brasil et al as follows:

(1) Anteriorly, a vertical plane going through the PNS, perpendicular to the midsagittal plane;

(2) Posteriorly, the posterior walls of the pharynx;

(3) Laterally, the lateral walls of the pharynx, including the entire length of the lateral pharyngeal projections;

(4) Inferiorly, a plane tangent to the medial caudal projection of the third cervical vertebra, perpendicular to the sagittal plane;

(5) Superiorly, the highest point of the nasopharynx, coinciding with the posterior portion of the choanae and consistent with the anterior limit.

Delimitation of the nasopharynx:

A line from sella (S) to nasion (N), another line through the posterior wall of the pharynx (PWF) to the sella-nasion line (S-N), and a line perpendicular to the PWF from basion (Ba) to the posterior nasal spine (PNS).

Delimitation of oropharynx:

A line starting from the third cervical vertebra (C3) to the PWF.

Delimitation of hypopharynx:

A line perpendicular to the PWF from the fourth cervical vertebra (C4)

Hyoid Triangle Measurements:

The hyoid triangle was determined by lines, planes, and angles, according to the method proposed by **Bibby and Preston.**

Table 2: Definitions of the measurements of the hyoid triangle method.

Measurement	*Description*	*Diagnostic value*
C3-RGn	Line drawn between the third cervical vertebra (C3) and the retrognathic point (RGn)	Anteroposterior position of the mandibular anterior region
C3-H	Line starting from the third cervical vertebra (C3) up to the uppermost point, anterior to the hyoid bone (H)	Anteroposterior position of the hyoid bone
H-RGn	Line with the uppermost point, anterior to hyoid bone(H) up to retrognathic point (RGn)	
H-H’	Line of the C3-RGn plane	Vertical position of

	perpendicular to the hyoid	the hyoid bone
HP Angle	Angle formed by the intersection of the hyoid plane(HP) (from the most anterior point of hyoid body to the most posterior and superior point of hyoid greater horn) with the C3-RGn plane	Angular position of the hyoid bone in relation to the mandible
AA-PNS	Line between the most anterior point of the atlas vertebra (AA) up to the posterior nasal spine (PNS)	Anteroposterior dimension of the upper bony airway
dhoriz-H	Distance between the most posterior point of the posterior wall of the pharynx (PWF) to the hyoid (H)	Dimension of the pharynx in the hyoid bone plane
dvert-H	Distance from the H point to the palatal plane parallel to the PTM line (PTM line: line of the centre of the pterygomaxillary fissure perpendicular to the palatine plane)	Position of the hyoid bone in relation to the middle facial third
PH-BaN	Angle formed between the hyoid plane (HP) and the	Relation between the hyoid bone and the

	basion-nasion line (BaN)	cranial base
HPPP	Angle formed by the hyoid plane (HP) and the palatal plane (PP)	Relation between the hyoid bone and the middle facial third

STATISTICAL ANALYSIS:

SPSS for windows 20.0 (Statistical Package for the Social Sciences, Chicago, IL) were used. Evaluation of results and statistical analysis was carried out using descriptive, correlation and regression analysis. In all the above mentioned tests, $P < 0.05$ was taken to be statistically significant. When the correlation values were between -1 and 0, then it is interpreted as negative correlation and when the correlation values were between 0 and 1, then it is interpreted as positive correlation.

Figures

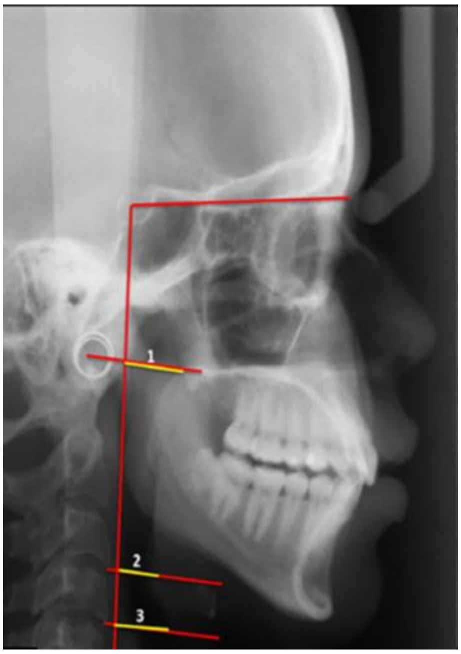


Figure 6 : Representation of pharyngeal sub regions level.

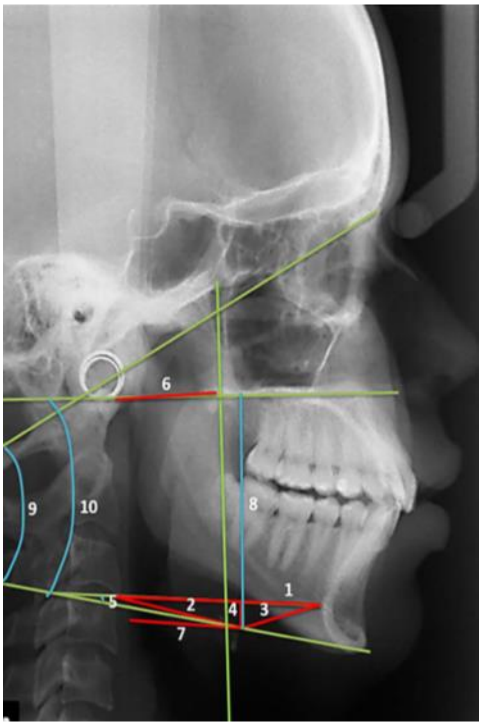


Figure 7: Representation of hyoid bone position measurements

Results

RESULTS

The present study is a retrospective study conducted in the Department of Oral medicine and Radiology, Ragas dental college and hospital from February 2019 to August 2019. The aim of the study is to correlate the relationship between the upper pharyngeal airway space and the position of hyoid bone. Total of 30 retrospective lateral cephalometric images were collected. The lateral cephalometric images were exported in the Scanora software and later the cephalometric landmarks were and measured according to *Brasil et al* for upper airway measurement and *Bibby and Preston* hyoid triangle method for analysing the position of hyoid bone. The data obtained from measuring 10 parameters were statistically analysed.

Parameter 1 (C3-RGn)

Measure the distance between the third cervical vertebra (C3) and the retrognathic point (RGn).

Parameter 2 (C3-H)

Measure the distance from the third cervical vertebra (C3) up to the uppermost point, anterior to the hyoid bone (H).

Parameter 3 (H-RGn)

Measure the distance from the uppermost point, anterior to hyoid bone (H) up to retrognathic point (RGn).

Parameter 4 (H-H')

Measure the length of the Line of the C3-RGn plane perpendicular to the hyoid bone.

Parameter 5 (HP Angle)

Measure the angle formed by the intersection of the hyoid plane (HP) (from the most anterior point of hyoid body to the most posterior and superior point of hyoid greater horn) with the C3-RGn plane.

Parameter 6 (AA-PNS)

Measure the distance between the most anterior point of the atlas vertebra (AA) up to the posterior nasal spine (PNS).

Parameter 7 (dhoriz-H)

Measure the distance between the most posterior point of the posterior wall of the pharynx (PWF) to the hyoid (H).

Parameter 8 (dvert-H)

Measure the distance from the H point to the palatal plane parallel to the PTM line (PTM line: line of the centre of the pterygomaxillary fissure perpendicular to the palatine plane).

Parameter 9 (PH-BaN)

Measure the angle formed between the hyoid plane (HP) and the basion-nasion line (BaN).

Parameter 10 (HPPP)

Measure the angle formed by the hyoid plane (HP) and the palatal plane (PP).

Parameter 11

The type of hyoid triangle present by joining C3-RGn, C3-H and H-RGn.

Results of the present study documents the following data:

Table 3: the frequency of sex group taken in this study, tells that out of 30 samples taken, 15 are female and 15 are male subjects.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	15	50.0	50.0	50.0
	Female	15	50.0	50.0	100.0
	Total	30	100.0	100.0	

Table 4: The descriptive analysis of age group taken in this study shows that the mean age group is 22 years.

	N	Minimum	Maximum	Mean	Std. Deviation
Age in years	30	16	28	21.97	3.034

The descriptive variables used in the measurement of hyoid bone space in relation to various levels of pharyngeal space and their correlation are also explained.

Table 5: the descriptive analysis of ***(Parameter 1 C3RGn)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	57.460	7.7789	43.0	72.1
Oropharynx	30	61.113	5.9035	50.0	75.9
Hypoharynx	30	20.073	5.7511	5.7	30.2
Total	90	46.216	19.7395	5.7	75.9

Table 6: Anterior posterior position of the mandibular anterior region ***(Parameter 1 C3-RGn)*** showed significant correlation with the hypopharynx with a P value of .000.

	(J) Group	Mean Difference (I-J)	Sig. (P value)
Nasopharynx	Oropharynx	-3.6533	.084
	Hypoharynx	37.3867*	.000
Oropharynx	Nasopharynx	3.6533	.084
	Hypoharynx	41.0400*	.000
Hypoharynx	Nasopharynx	-37.3867*	.000
	Oropharynx	-41.0400*	.000

Table 7: the descriptive analysis of ***(Parameter 2 C3-H)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	64.460	8.8616	51.4	84.7
Oropharynx	30	29.397	4.6301	19.5	37.0
Hypoharynx	30	10.960	2.8424	5.2	18.1
Total	90	34.939	23.0898	5.2	84.7

Table 8: The anteroposterior dimension of the hyoid bone ***(Parameter 2 C3 – H)*** showed significant correlation with nasopharynx, oropharynx and hypopharynx region with P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	35.0633*	.000
	Hypoharynx	53.5000*	.000
Oropharynx	Nasopharynx	-35.0633*	.000
	Hypoharynx	18.4367*	.000
Hypoharynx	Nasopharynx	-53.5000*	.000
	Oropharynx	-18.4367*	.000

Table 9: the descriptive analysis of ***(Parameter 3 H-RGn)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	73.650	8.6057	55.8	88.7
Oropharynx	30	45.467	6.3672	32.4	57.0
Hypoharynx	30	13.727	3.7717	4.4	20.8
Total	90	44.281	25.4535	4.4	88.7

Table 10: the distance from the uppermost point, anterior to hyoid bone up to retrognathic point ***(Parameter 3 – H-RGn)*** showed significant correlation with nasopharynx, oropharynx and hypopharynx region with P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	28.1833*	.000
	Hypoharynx	59.9233*	.000
Oropharynx	Nasopharynx	-28.1833*	.000
	Hypoharynx	31.7400*	.000
Hypoharynx	Nasopharynx	-59.9233*	.000
	Oropharynx	-31.7400*	.000

Table 11: the descriptive analysis of ***(Parameter 4 H-H')*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	69.980	9.5217	56.3	90.5
Oropharynx	30	27.160	3.2102	20.4	31.3
Hypoharynx	30	18.687	4.3967	11.2	26.8
Total	90	38.609	23.4286	11.2	90.5

Table 12: the vertical position of hyoid bone ***(Parameter 4 – H-H')*** showed significant correlation in nasopharynx, oropharynx and hypopharynx regions with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	42.8200*	.000
	Hypoharynx	51.2933*	.000
Oropharynx	Nasopharynx	-42.8200*	.000
	Hypoharynx	8.4733*	.000
Hypoharynx	Nasopharynx	-51.2933*	.000
	Oropharynx	-8.4733*	.000

Table 13: the descriptive analysis of ***(Parameter 5 - HP angle)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	300.060	50.7558	140.6	363.5
Oropharynx	30	269.040	30.1196	219.7	356.5
Hypoharynx	30	257.657	11.9004	236.9	276.0
Total	90	275.586	38.8056	140.6	363.5

Table 14: the angular position of the hyoid bone in relation to the mandible ***(Parameter 5 – HP angle)*** showed significant correlation in hypopharynx region with a P value of .000 and poor correlation in the nasopharynx region with a p value of .002.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	31.0200*	.002
	Hypoharynx	42.4033*	.000
Oropharynx	Nasopharynx	-31.0200*	.002
	Hypoharynx	11.3833	.417
Hypoharynx	Nasopharynx	-42.4033*	.000
	Oropharynx	-11.3833	.417

Table 15: the descriptive analysis of ***(Parameter 6 AA – PNS***) with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	13.090	3.6269	5.5	19.9
Oropharynx	30	49.017	4.9280	41.4	59.6
Hypoharynx	30	62.237	14.0099	2.1	81.7
Total	90	41.448	22.6321	2.1	81.7

Table 16: The anteroposterior dimension of the upper bony airway ***(Parameter 6 AA-PNS)*** shows significant correlation in the nasopharynx, oropharynx and hyopharynx region with a P value of .00.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	-35.9267*	.000
	Hypoharynx	-49.1467*	.000
Oropharynx	Nasopharynx	35.9267*	.000
	Hypoharynx	-13.2200*	.000
Hypoharynx	Nasopharynx	49.1467*	.000
	Oropharynx	13.2200*	.000

Table 17: the descriptive analysis of ***(Parameter 7 dhoriz – H)*** angle with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	67.833	12.0262	24.4	84.5
Oropharynx	30	25.280	3.7768	18.6	35.0
Hypoharynx	30	28.593	5.2309	17.7	40.1
Total	90	40.569	20.9378	17.7	84.5

Table 18: the dimension of the pharynx in the hyoid bone plane ***(Parameter 7 dhoriz – H)*** showed significant correlation in the nasopharynx and oropharynx region with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	42.5533*	.000
	Hypoharynx	39.2400*	.000
Oropharynx	Nasopharynx	-42.5533*	.000
	Hypoharynx	-3.3133	.239
Hypoharynx	Nasopharynx	-39.2400*	.000
	Oropharynx	3.3133	.239

Table 19: the descriptive analysis of ***(Parameter 8 dvert – H)*** angle with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	14.910	10.1851	.0	41.4
Oropharynx	30	57.973	8.1922	42.8	73.2
Hypoharynx	30	69.540	7.5586	56.0	85.9
Total	90	47.474	25.1597	.0	85.9

Table 20: the position of the hyoid bone in relation to the middle facial third ***(Parameter 8 dvert – H)*** showed significant correlation in the nasopharynx, oropharynx and hypopharynx regions with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	-43.0633*	.000
	Hypoharynx	-54.6300*	.000
Oropharynx	Nasopharynx	43.0633*	.000
	Hypoharynx	-11.5667*	.000
Hypoharynx	Nasopharynx	54.6300*	.000
	Oropharynx	11.5667*	.000

Table 21: the descriptive analysis of ***(Parameter 9 PH – BaN)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	283.403	40.6174	104.4	326.7
Oropharynx	30	169.843	17.2547	114.9	202.4
Hypoharynx	30	275.453	8.1160	260.2	287.0
Total	90	242.900	58.0113	104.4	326.7

Table 22: the relation between the hyoid bone and the base of the skull ***(Parameter 9 PH–BaN)*** showed significant correlation in the oropharynx region with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	113.5600*	.000
	Hypoharynx	7.9500	.463
Oropharynx	Nasopharynx	-113.5600*	.000
	Hypoharynx	-105.6100*	.000
Hypoharynx	Nasopharynx	-7.9500	.463
	Oropharynx	105.6100*	.000

Table 23: the descriptive analysis of ***(Parameter 10 HP – PP)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharyx	30	213.233	77.9254	98.7	339.5
Oropharynx	30	273.287	28.6255	204.1	340.6
Hypoharynx	30	263.700	11.6520	237.9	287.7
Total	90	250.073	54.6954	98.7	340.6

Table 24: the angular relationship between the hyoid bone and the middle third face ***(Parameter 10 HP – PP)*** showed significant correlation in the nasopharynx region with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	-60.0533*	.000
	Hypoharynx	-50.4667*	.000
Oropharynx	Nasopharynx	60.0533*	.000
	Hypoharynx	9.5867	.724
Hypoharynx	Nasopharynx	50.4667*	.000
	Oropharynx	-9.5867	.724

Table 25: the frequency of types of hyoid triangle in the study population.

This table shows that more commonly observed type of hyoid triangle in this population is ***Type 5 (narrow inverted triangle).***

Type of hyoid triangle	No of samples observed
Type 1	nil
Type 2	3
Type 3	2
Type 4	9
Type 5	16

Tables and Graphs

Table 3: the frequency of sex group taken in this study, tells that out of 30 samples taken, 15 are female and 15 are male subjects.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	15	50.0	50.0	50.0
	Female	15	50.0	50.0	100.0
	Total	30	100.0	100.0	

Table 4: The descriptive analysis of age group taken in this study shows that the mean age group is 22 years.

	N	Minimum	Maximum	Mean	Std. Deviation
Age in years	30	16	28	21.97	3.034

The descriptive variables used in the measurement of hyoid bone space in relation to various levels of pharyngeal space and their correlation are also explained.

Table 5: the descriptive analysis of ***(Parameter 1 C3RGn)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	57.460	7.7789	43.0	72.1
Oropharynx	30	61.113	5.9035	50.0	75.9
Hypopharynx	30	20.073	5.7511	5.7	30.2
Total	90	46.216	19.7395	5.7	75.9

Table 6: Anterior posterior position of the mandibular anterior region ***(Parameter 1 C3-RGn)*** showed significant correlation with the hypopharynx with a P value of .000.

	(J) Group	Mean Difference (I-J)	Sig. (P value)
Nasopharynx	Oropharynx	-3.6533	.084
	Hypoharynx	37.3867*	.000
Oropharynx	Nasopharynx	3.6533	.084
	Hypoharynx	41.0400*	.000
Hypoharynx	Nasopharynx	-37.3867*	.000
	Oropharynx	-41.0400*	.000

Table 7: the descriptive analysis of ***(Parameter 2 C3-H)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	64.460	8.8616	51.4	84.7
Oropharynx	30	29.397	4.6301	19.5	37.0
Hypoharynx	30	10.960	2.8424	5.2	18.1
Total	90	34.939	23.0898	5.2	84.7

Table 8: The anteroposterior dimension of the hyoid bone ***(Parameter 2 C3 – H)*** showed significant correlation with nasopharynx, oropharynx and hypopharynx region with P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	35.0633*	.000
	Hypoharynx	53.5000*	.000
Oropharynx	Nasopharynx	-35.0633*	.000
	Hypoharynx	18.4367*	.000
Hypoharynx	Nasopharynx	-53.5000*	.000
	Oropharynx	-18.4367*	.000

Table 9: the descriptive analysis of ***(Parameter 3 H-RGn)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	73.650	8.6057	55.8	88.7
Oropharynx	30	45.467	6.3672	32.4	57.0
Hypoharynx	30	13.727	3.7717	4.4	20.8
Total	90	44.281	25.4535	4.4	88.7

Table 10: the distance from the uppermost point, anterior to hyoid bone up to retrognathic point ***(Parameter 3 – H-RGn)*** showed significant correlation with nasopharynx, oropharynx and hypopharynx region with P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	28.1833*	.000
	Hypoharynx	59.9233*	.000
Oropharynx	Nasopharynx	-28.1833*	.000
	Hypoharynx	31.7400*	.000
Hypoharynx	Nasopharynx	-59.9233*	.000
	Oropharynx	-31.7400*	.000

Table 11: the descriptive analysis of ***(Parameter 4 H-H')*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	69.980	9.5217	56.3	90.5
Oropharynx	30	27.160	3.2102	20.4	31.3
Hypoharynx	30	18.687	4.3967	11.2	26.8
Total	90	38.609	23.4286	11.2	90.5

Table 12: the vertical position of hyoid bone ***(Parameter 4 – H-H')*** showed significant correlation in nasopharynx, oropharynx and hypopharynx regions with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	42.8200*	.000
	Hypoharynx	51.2933*	.000
Oropharynx	Nasopharynx	-42.8200*	.000
	Hypoharynx	8.4733*	.000
Hypoharynx	Nasopharynx	-51.2933*	.000
	Oropharynx	-8.4733*	.000

Table 13: the descriptive analysis of ***(Parameter 5 - HP angle)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	300.060	50.7558	140.6	363.5
Oropharynx	30	269.040	30.1196	219.7	356.5
Hypoharynx	30	257.657	11.9004	236.9	276.0
Total	90	275.586	38.8056	140.6	363.5

Table 14: the angular position of the hyoid bone in relation to the mandible ***(Parameter 5 – HP angle)*** showed significant correlation in hypopharynx region with a P value of .000 and poor correlation in the nasopharynx region with a p value of .002.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	31.0200*	.002
	Hypoharynx	42.4033*	.000
Oropharynx	Nasopharynx	-31.0200*	.002
	Hypoharynx	11.3833	.417
Hypoharynx	Nasopharynx	-42.4033*	.000
	Oropharynx	-11.3833	.417

Table 15: the descriptive analysis of ***(Parameter 6 AA – PNS***) with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	13.090	3.6269	5.5	19.9
Oropharynx	30	49.017	4.9280	41.4	59.6
Hypoharynx	30	62.237	14.0099	2.1	81.7
Total	90	41.448	22.6321	2.1	81.7

Table 16: The anteroposterior dimension of the upper bony airway ***(Parameter 6 AA-PNS)*** shows significant correlation in the nasopharynx, oropharynx and hyopharynx region with a P value of .00.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	-35.9267*	.000
	Hypoharynx	-49.1467*	.000
Oropharynx	Nasopharynx	35.9267*	.000
	Hypoharynx	-13.2200*	.000
Hypoharynx	Nasopharynx	49.1467*	.000
	Oropharynx	13.2200*	.000

Table 17: the descriptive analysis of ***(Parameter 7 dhoriz – H)*** angle with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	67.833	12.0262	24.4	84.5
Oropharynx	30	25.280	3.7768	18.6	35.0
Hypoharynx	30	28.593	5.2309	17.7	40.1
Total	90	40.569	20.9378	17.7	84.5

Table 18: the dimension of the pharynx in the hyoid bone plane ***(Parameter 7 dhoriz – H)*** showed significant correlation in the nasopharynx and oropharynx region with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	42.5533*	.000
	Hypoharynx	39.2400*	.000
Oropharynx	Nasopharynx	-42.5533*	.000
	Hypoharynx	-3.3133	.239
Hypoharynx	Nasopharynx	-39.2400*	.000
	Oropharynx	3.3133	.239

Table 19: the descriptive analysis of ***(Parameter 8 dvert – H)*** angle with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	14.910	10.1851	.0	41.4
Oropharynx	30	57.973	8.1922	42.8	73.2
Hypoharynx	30	69.540	7.5586	56.0	85.9
Total	90	47.474	25.1597	.0	85.9

Table 20: the position of the hyoid bone in relation to the middle facial third ***(Parameter 8 dvert – H)*** showed significant correlation in the nasopharynx, oropharynx and hypopharynx regions with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	-43.0633*	.000
	Hypoharynx	-54.6300*	.000
Oropharynx	Nasopharynx	43.0633*	.000
	Hypoharynx	-11.5667*	.000
Hypoharynx	Nasopharynx	54.6300*	.000
	Oropharynx	11.5667*	.000

Table 21: the descriptive analysis of ***(Parameter 9 PH – BaN)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharynx	30	283.403	40.6174	104.4	326.7
Oropharynx	30	169.843	17.2547	114.9	202.4
Hypoharynx	30	275.453	8.1160	260.2	287.0
Total	90	242.900	58.0113	104.4	326.7

Table 22: the relation between the hyoid bone and the base of the skull ***(Parameter 9 PH–BaN)*** showed significant correlation in the oropharynx region with a P value of .000.

(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	113.5600*	.000
	Hypoharynx	7.9500	.463
Oropharynx	Nasopharynx	-113.5600*	.000
	Hypoharynx	-105.6100*	.000
Hypoharynx	Nasopharynx	-7.9500	.463
	Oropharynx	105.6100*	.000

Table 23: the descriptive analysis of ***(Parameter 10 HP – PP)*** with mean, standard deviation and maximum and minimum values at the level of nasopharynx, oropharynx and hypopharynx have been explained.

	N	Mean	Std. Deviation	Minimum	Maximum
Nasopharyx	30	213.233	77.9254	98.7	339.5
Oropharynx	30	273.287	28.6255	204.1	340.6
Hypoharynx	30	263.700	11.6520	237.9	287.7
Total	90	250.073	54.6954	98.7	340.6

Table 24: the angular relationship between the hyoid bone and the middle third face ***(Parameter 10 HP – PP)*** showed significant correlation in the nasopharynx region with a P value of .000.

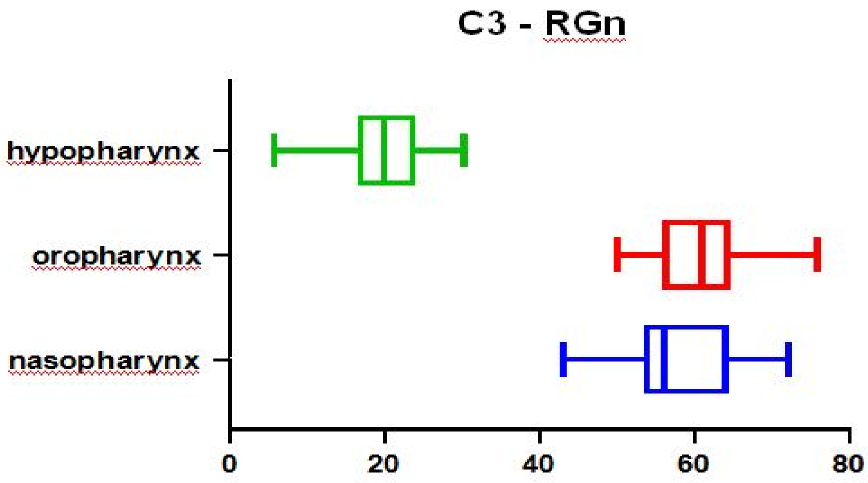
(I) Group	(J) Group	Mean Difference (I-J)	Sig.
Nasopharynx	Oropharynx	-60.0533*	.000
	Hypoharynx	-50.4667*	.000
Oropharynx	Nasopharynx	60.0533*	.000
	Hypoharynx	9.5867	.724
Hypoharynx	Nasopharynx	50.4667*	.000
	Oropharynx	-9.5867	.724

Table 25: The frequency of types of hyoid triangle in the study population.

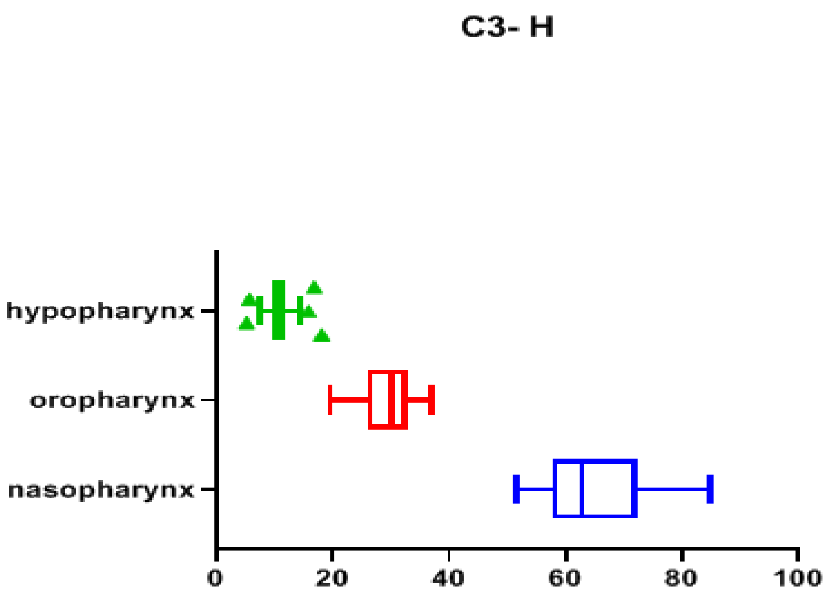
This table shows that more commonly observed type of hyoid triangle in this population is ***Type 5 (narrow inverted triangle).***

Type of hyoid triangle	No of samples observed
Type 1	nil
Type 2	3
Type 3	2
Type 4	9
Type 5	16

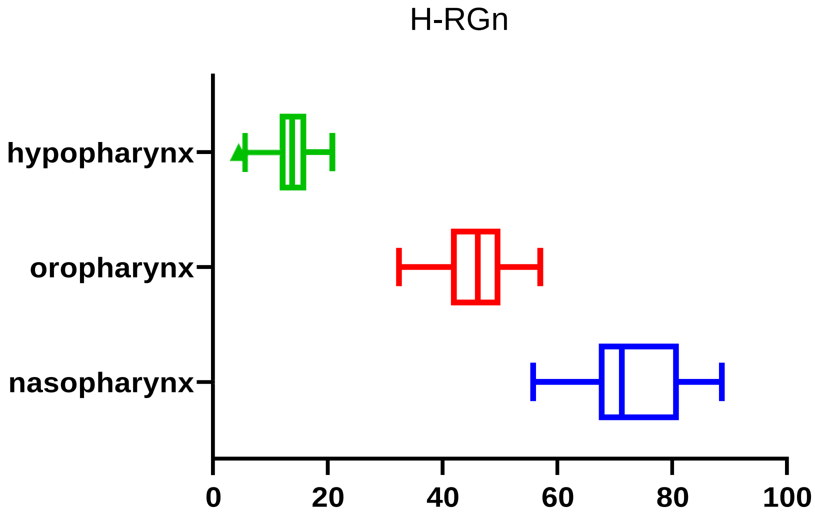
Graph 1: The multiple comparison of C3RGn between nasopharynx, oropharynx and hypopharynx.



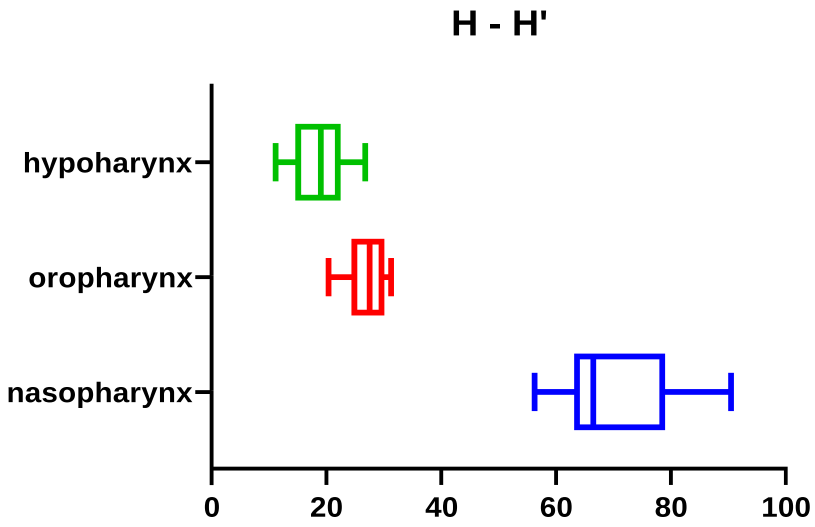
Graph 2: The multiple comparison of C3 - H between nasopharynx, oropharynx and hypopharynx.



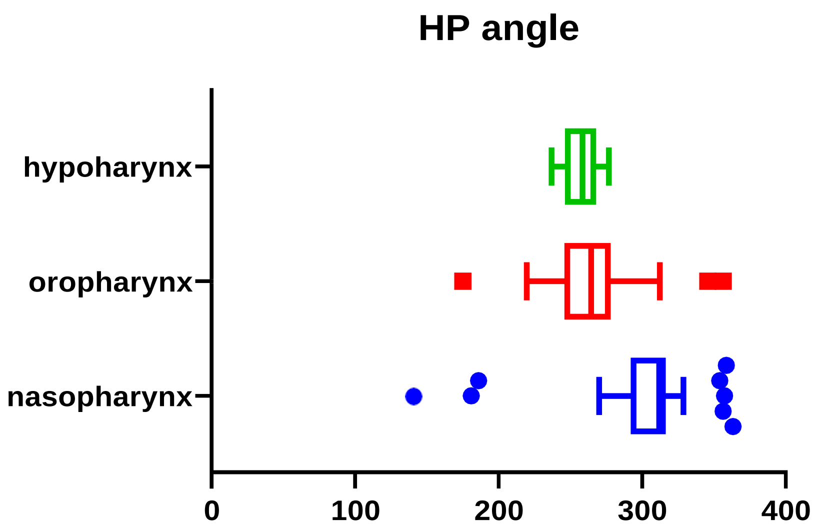
Graph 3: The multiple comparison of H-RGn between nasopharynx, oropharynx and hypopharynx.



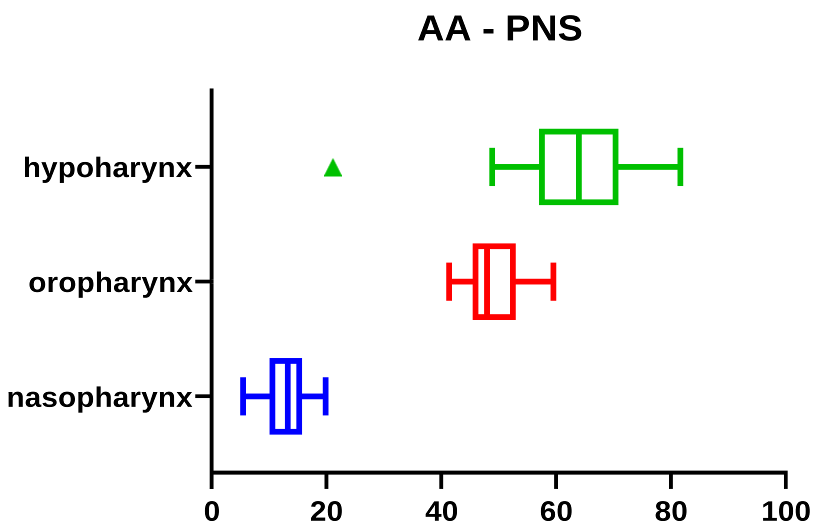
Graph 4: The multiple comparison of H-RGn between nasopharynx, oropharynx and hypopharynx.



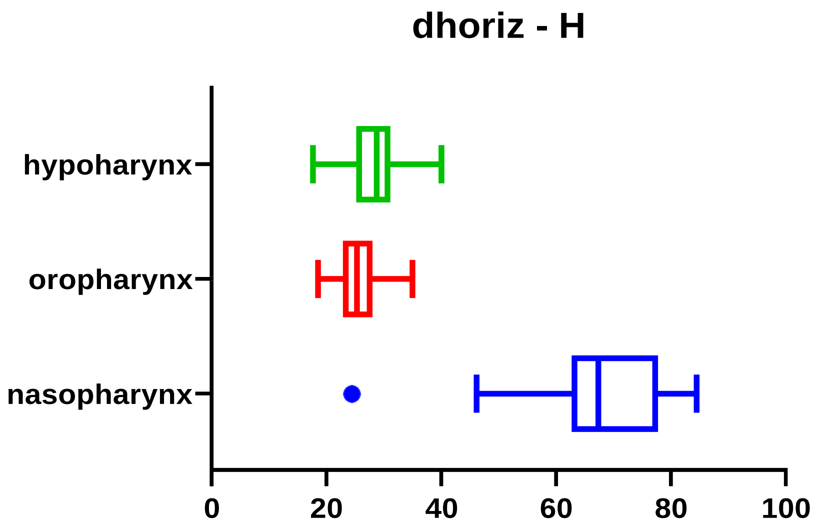
Graph 5: The multiple comparison of HP angle between nasopharynx, oropharynx and hypopharynx.



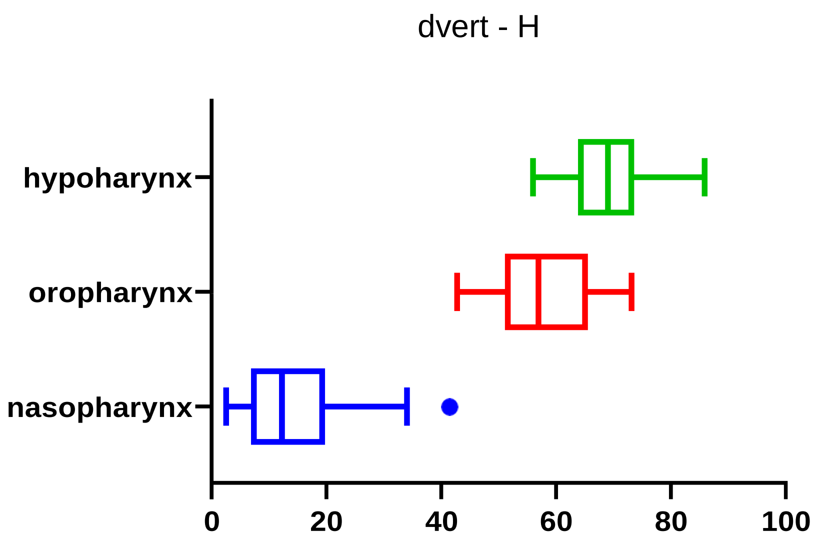
Graph 6: The multiple comparison of AA - PNS between nasopharynx, oropharynx and hypopharynx.



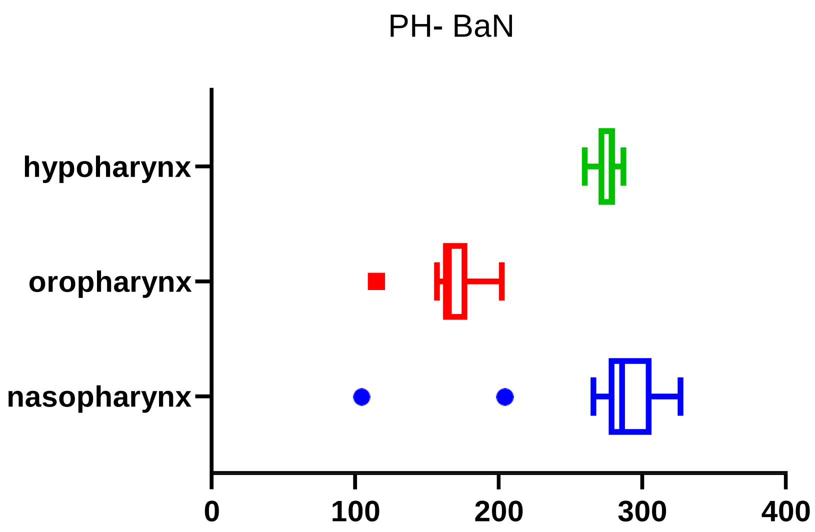
Graph 7: The multiple comparison of dhoriz-H between nasopharynx, oropharynx and hypopharynx.



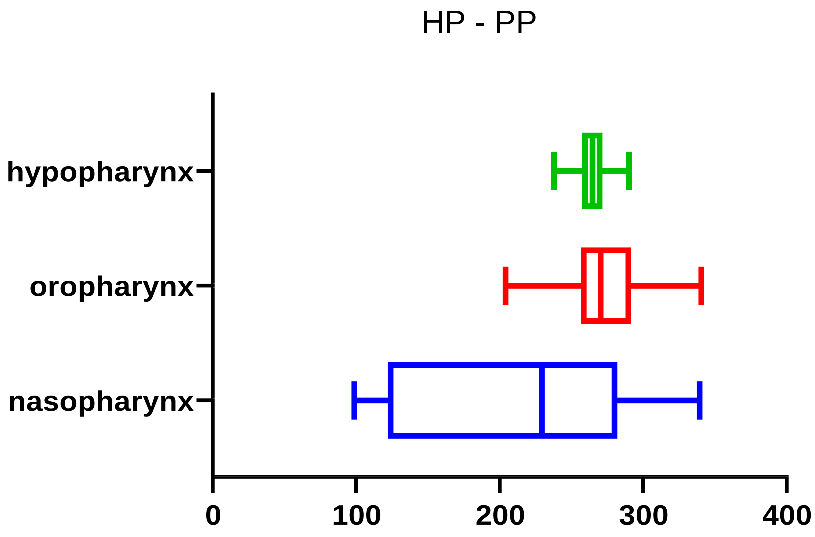
Graph 8: The multiple comparison of dvert-H between nasopharynx, oropharynx and hypopharynx.



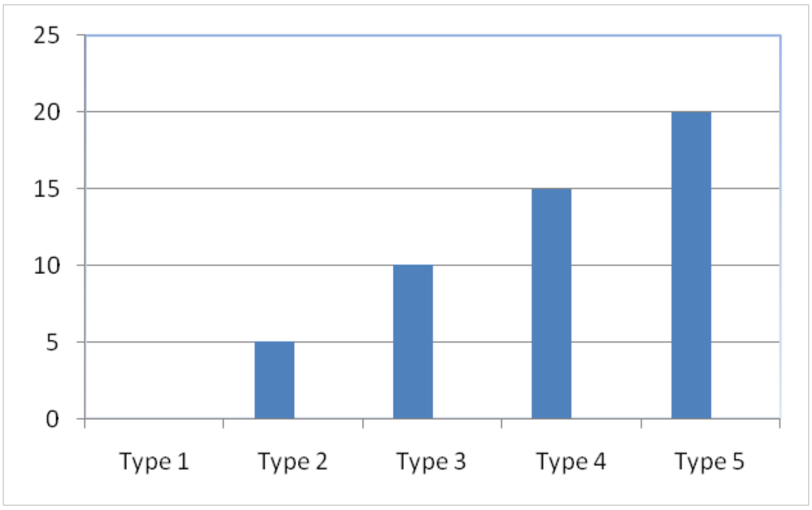
Graph 9: The multiple comparison of dvert-H between nasopharynx, oropharynx and hypopharynx.



Graph 10: The multiple comparison of dvert-H between nasopharynx, oropharynx and hypopharynx.



Graph 11: Frequency of type of hyoid triangle.



Discussion

DISCUSSION

Craniofacial growth and occlusion are highly influenced by the upper airway, thus making it an integral part of orthodontics [2]. Orthodontists believe that evaluation of upper airway space along with its related structures like hyoid bone should be an integral part of orthodontic diagnosis and treatment planning, as the upper pharyngeal airway in conjunction with its surrounding structures, is responsible for the physiologic processes of swallowing, vocalization, and respiration [14]. The hyoid bone is connected to the pharynx, mandible, and cranium by muscles and ligaments. The hyoid bone and its connecting muscles are also part of the oropharyngeal complex. Without the hyoid bone, our facility for maintaining an airway, swallowing, preventing regurgitation, and maintaining the upright postural position of the head could not be controlled as carefully [38].

Various orthodontic treatment modalities are used for the correction of facial deformities. An important aspect of these treatments are the effect of skeletal movements in the surrounding structures [20]. Maxillomandibular advancement leads to anterior movements of the soft palate, base of the tongue, hyoid bone, and anterior pharyngeal tissues, resulting in increases in the volumes of the nasopharynx, oropharynx, and hypopharynx, and therefore increasing the posterior airway space [52]. Whereas, an mandibular setback surgery can cause relative narrowing of the pharyngeal airway and a significant posterior movement of the hyoid bone. The main areas of change are the soft palate (nasopharynx), the lateral walls of pharynx (oropharynx) and the base of the tongue (hypopharynx) in the lateral cephalometry, when the hyoid bone position was highly correlated to the measures of sub regions of the pharynx in a orthodontic treatment process [14,23,35].

This is a retrospective study conducted in the Department of Oral medicine and Radiology, Ragas dental college and hospital from February 2019 to August 2019. The aim of the study is to correlate the position of hyoid bone with the measures of the nasopharynx, oropharynx and hypopharynx respectively. Total of 30 retrospective lateral cephalometric images were collected, of which 15 are male and female respectively. The lateral cephalometric images were exported in the Scanora software and later the cephalometric landmarks were and measured according to ***Brasil et al*** for upper airway measurement and ***Bibby and Preston*** hyoid triangle method for analysing the position of hyoid bone. The data obtained from measuring 10 parameters were statistically analysed.

Considering the hyoid triangle measurements, ***type V hyoid triangle (narrow inverted triangle)*** is the common type observed in this study. Measuring each hyoid bone parameters at the level of nasopharynx, oropharynx and hyopharynx, the anteroposterior position of the mandibular anterior region ***(C3-RGn- parameter 1)*** showed significant correlation with **hypopharynx region,** similar observation was made in ***Trenouth and Timms***

[32] and ***Eliana Dantas da Costaa et al*** [12] this occurs because of the influence of mandible and associated musculature in changing the position of hyoid bone, whereas ***Ferraz et al*** [23] concluded that no statistical significant differences in the mandible and hyoid bone position.

The anteroposterior dimension of the hyoid bone **(C3 – H- parameter 2)** showed significant correlation with **nasopharynx, oropharynx and hypopharynx** region,smilar observation was in ***Adamidis and Spyropoulos*** [22],whereas in ***Eliana Dantas da Costaa et al*** [12] has reported a poor correlation between position of hyoid bone and sub regions of upper airway space.

There was significant correlation between ***(H-RGn- parameter 3)*** and **nasopharynx, oropharynx and hypopharynx** regions, which is according to ***Eung-Kwon et al*** [39] H-RGn differs according to the hyoid bone position closer to the mandibular plane and more posteriorly located, whereas in Eliana ***Dantas da Costaa et al*** [12] has reported a poor correlation between H-RGn and sub regions of upper airway space.

The vertical position of the hyoid bone ***(H-H'- parameter 4)*** showed significant correlation with **nasopharynx, oropharynx and hypopharynx region,** similar observation was seen in ***Adamidis et al*** [37], whereas in ***Kollias et al*** [31]***, Trenouth and Timms*** [32]***, Eliana Dantas da Costaa et al*** [12] has reported a poor correlation between vertical position of hyoid bone and sub regions of upper airway space.

The angular position of the hyoid bone in relation the mandible ***(HP angle – parameter 5)*** showed significant correlation in the **nasopharynx region** and poor correlation in the **hypopharynx region**, which is similar to the observation made in ***Tallgren and Solow et al*** [25] that Vertical changes in the position of the hyoid bone in relation to the upper face followed the pattern of increase or decrease of the mandibular inclination, whereas the horizontal changes followed mainly the changes in both cervical inclination and craniocervical angulation, the poor correlation in the hypopharynx is similar to the observation made in ***Eliana Dantas da Costaa et al*** [12].

The anteroposterior dimension of the upper bony airway ***(AA-PNS- parameter 6)*** shows significant correlation in the **nasopharynx, oropharynx and hyopharynx region,** a similar finding is seen in ***Eliana Dantas da Costaa et al*** [12]***, Adamidis et al*** [36] ***and Park et al*** [48], this significant correlation tells the influence of hyoid bone position on the upper airway space obstruction, which plays a major role in development of malocclusions.

The dimension of the pharynx in the hyoid bone plane ***(dhoriz-H – parameter 7)*** shows significant correlation in the **nasopharynx region**, which is similar to the observation made in ***Neelapu et al*** [33] ***and Batool et al*** [42] this because of the close proximity to soft tissue area like soft palate, whereas in ***Eliana Dantas da Costaa et al*** [12] have showed significant relation to the hypopharynx region.

The position of the hyoid bone in relation to the middle facial third ***(dvert – H – parameter 8)*** showed significant correlation in the **nasopharynx, oropharynx and hyopharynx region**, which is similar to the observation made in ***Kuroda et al* [26] *and Ameryi et al* [22]**. This finding could be attributed to the muscular attachment to the hyoid bone and the mandible, so it is moving backward and forward following the mandibular movement in the sagittal plane, and it could be instrumental in the establishment of specific structural elements of the jaws and occlusion of teeth which is of great interest to the orthodontists. Whereas studies like ***Aboudara et al* [45], *Sumanth et al* [23]** have stated that there is no correlation between the position of the hyoid bone in relation to the middle third of face.

The relation between the hyoid bone and the cranial base ***(PH –BaN – parameter 9)*** showed significant correlation in the **oropharynx region,** which is similar to the observation made in ***Schendel SA, Epker BN.* [52]; *Ulusoy et al and Aksu et al* [4],**because they influence soft tissue structures in oropharynx, which is implicated in myofunctional orthodontic therapy to avoid the relapse. However, in ***Eliana Dantas da Costaa et al* [12]** has reported a poor correlation between the hyoid bone and the cranial base and sub regions of upper airway space.

The angular relation between the hyoid bone and the middle facial third ***(HP – PP – parameter 10)*** showed a significant correlation in the **nasopharynx region**, which is similar to the finding observed in ***Kuroda et al* [26], *Ameryi et al* [22]**. This finding could be attributed to the muscular attachment to the hyoid bone and the mandible, so it is moving backward and forward following the mandibular movement in the sagittal plane. Whereas studies like ***Aboudara et al*** [45]***, Sumanth et al*** [23]***, and Eliana Dantas da Costaa et al*** [12] have stated that there is no correlation between the position of the hyoid bone in relation to the middle third of face.

The results of this study shows that these parameters used to measure the position of hyoid bone showed a highly significant correlation with the sub regions of the upper pharynx likely, the nasopharynx, oropharynx and the hypopharynx respectively. So these reliable cephalometric parameters can be used in the orthodontic diagnosis of malocclusions even during the post treatment phase to avoid the relapse of the treatment.

Summary and Conclusion

SUMMARY AND CONCLUSION

The present study titled ***"Pharyngeal airway analysis in relation to position of hyoid bone using lateral cephalometrics "*** was conducted in the Department of Oral Medicine and Radiology, Ragas Dental College and Hospital, Chennai in order to evaluate the correlation between the pharyngeal airway sub regions with the position of the hyoid bone in lateral cephalometric.This study is a retrospective study conducted in 30 lateral cephalometric images of patients present in the department of Oral Medicine and Radiology, of which 15 images were of male and female patients aged between 16 to 28 years.

The study documents the following data:

- The cephalometric landmarks representing the position of hyoid bone were considered as 10 parameters; each of these parameters were correlated to the level of nasopharynx, oropharynx and hypopharynx respectively.
- The type of hyoid triangle present in the study population.

Correlation of parameters with levels of pharynx:

- At the level of ***nasopharynx***, the anteroposterior position of the hyoid bone **(Parameter 2 : C3-H)**, The distance from the anterior most point of hyoid bone to the retrognathic point **(Parameter 3 : H-RGn),** the vertical position of hyoid bone **(Parameter 4: H-H')**,the anteroposterior dimension of the bony upper airway **(Parameter 6: AA-PNS),**The dimension of the pharynx in the hyoid bone plane **(Parameter 7 : dhoriz-H),**the linear **(Parameter 8 : dvert-H)** and the angular relation between the hyoid bone and the middle third of face **(Parameter 10 : HP-PP)** showed a significant correlation with a P value of 0.000 and the angular relation between hyoid bone and the mandible **(Parameter 5 : HP angle)** showed a poor correlation with a P value of 0.02. This gives us an inference that the anteroposterior position of hyoid bone is highly influenced by the nasopharynx level.

- At the level of ***oropharynx***, the anteroposterior position of the hyoid bone **(Parameter 2: C3-H),** The distance from the anterior most point of hyoid bone to the retrognathic point **(Parameter 3: H-RGn),** the vertical position of hyoid bone **(Parameter 4: H-H'),**the anteroposterior dimension of the bony upper airway **(Parameter 6: AA-PNS),**the linear relation between the hyoid bone and the middle third of face **(Parameter 8: dvert-H)** and the relation between the hyoid bone and the cranial base **(Parameter 9: PH-BaN)** showed significant correlation with a P value of 0.000.
- At the level of **hypopharynx,** , the anteroposterior position of the mandibular anterior region **(Parameter 1: C3-RGn**), the anteroposterior position of the hyoid bone **(Parameter 2: C3-H),** The distance from the anterior most point of hyoid bone to the retrognathic point **(Parameter 3: H-RGn)**, the vertical position of hyoid bone

(Parameter 4: H-H'),the anteroposterior dimension of the bony upper airway **(Parameter 6: AA-PNS)**,the angular position of hyoid bone and mandible **(Parameter 5: HP angle)**, the linear relation between the hyoid bone and the middle third of face **(Parameter 8: dvert-H)** and the relation between the hyoid bone and the cranial base **(Parameter 9: PH-BaN)** showed significant correlation with a P value of 0.000.

Type of hyoid triangle:

- In this study population **Type V (inverted triangle)** is most commonly observed one.

This study was an effort to enumerate the importance of correlation of the sub regions of the pharyngeal airway with position of hyoid bone in the lateral cephalogram. These structures play important role in the development of malocclusions, so it is important to know their correlation. If this diagnostic parameter is included in the orthodontic treatment plan, the treatment outcome of surgical, functional and contemporary orthodontics would be better by avoiding unnecessary relapse.

In conclusion, we suggest that pharyngeal airway analysis in relation to hyoid bone position can be used as a diagnostic tool for malocclusions in orthodontics.The present involved a small sample size and needs to be confirmed in larger longitudinal population studies. Further research can be directed at dividing the study population according to the skeletal malocclusion class, this would enumerate more details helping in proper treatment planning.

Bibilography

BIBILIOGRAPHY

1. ***Agrawal MS, Agrawal JM, Patni V, Nanjannawar L***. An evaluation of the reproducibility of landmark identification in traditional versus computer-assisted digital cephalometric analysis system. APOS Trends Orthod 2015; 5:103-10.
2. ***Al-Qahtani ND***. Impact of different orthodontic treatment modalities on Airway. Pak J Med Sci. 2016;32(1):249-252.
3. ***Antoine Daraze, Myriam Delatte, Giuseppe Liistro, and Zeina Majzoub.*** Cephalometrics of Pharyngeal Airway Space in Lebanese Adults. International Journal of Dentistry (2017) -3959456.
4. ***Anusuya V, Jena AK, Sharan J.*** Effects of functional appliance treatment on pharyngeal airway passage dimensions in Class II malocclusion subjects with retrognathic mandibles: A systematic review. APOS Trends Orthod 2019;9(3):138-48.
5. ***Arvind Hariharan et al.*** The reliability of cephalometric measurements in oral and maxillofacial imaging: Cone beam computed tomography versus two‑dimensional digital cephalograms. Indian J Dent Res 2016; 27:370-7.
6. ***Bibby and Preston.*** The Hyoid Triangle. Am.J.Orthod. 1981.
7. ***Chang-Min Sheng, Li-Hsiang Lin and Yu Su.*** Developmental Changes in Pharyngeal Airway Depth and Hyoid Bone Position from Childhood to Young Adulthood. Angle Orthodontist (2009), Vol 79 - 3.

8. ***Chokotiya H, Banthia A, Rao SK, Choudhry K, Sharma P and Awasthi N.*** A Study on the Evaluation of Pharyngeal Size in Different Skeletal Patterns– A Radiographic Study the Journal of Contemporary Dental Practice, October 2018; 19 (10):1278-1283.

9. ***Damstra et al.*** Reliability and the smallest detectable differences of lateral cephalometric. Am J Orthod Dentofacial Orthop 2010; 138:546.e1-546.e8.

10. ***Eduardo Sanches Goncales.*** Computerized Cephalometric Study of the Pharyngeal Airway Space in Patients Submitted to Orthognathic Surgery. J. Maxillofac. Oral Surg. (July–Sept 2014) 13(3):253–258.

11. ***Ehsan Eslamia et al.*** Are three-dimensional airway evaluations obtained through computed and cone-beam computed tomography scans predictable from lateral cephalograms? A systematic review of evidence. Angle Orthodontist, Vol 87, No 1, 2017.

12. ***Eliana Dantas da Costaa et al.*** Correlation between the position of hyoid bone and subregions of the pharyngeal airway space in lateral cephalometry and cone beam computed tomography. Angle Orthod. 2017; 87:688 – 695.

13. ***Entrenas I, González-Chamorro E, Álvarez-Abad C, Muriel J, Menéndez-Díaz I, CoboT.*** Evaluation of changes in the upper airway after Twin Block treatment in patients with Class II malocclusion. Clin Exp Dent Res. 2019;5:259–268.

14. ***Erwin Rojas, Rodrigo Corvalán , Eduardo Messen, Paulo Sandova***. Upper airway assessment in Orthodontics: a review. Odontoestomatología vol.19 no.30 Montevideo dic. 2017.

15. ***Gnanam RP, Kumar TS, Prabakar K, Raja S***. Position of hyoid bone in atypical deglutition –A pilot study. J Indian Acad Dent Spec Res 2016; 3:10-3.

16. ***Gupta S, Subrahmanya RM.*** Assessment of oropharyngeal widths in individuals with different facial skeletal patterns. Nitte Univ J Health Sci 2104; 4:34-8.

17. ***Horner, R. L., & Guz***, A. Some factors affecting the maintenance of upper airway patency in man. Respiratory Medicine 1991, 85, 27–30.

18. ***Indu Ayappa and David M. Rapoport.*** The upper airway in sleep: physiology of the pharynx, Physiological Review. Sleep Medicine Reviews, Vol. 7, No. 1,, 2003.

19. ***Iveta Indriksone and Gundega Jakobsone.*** The influence of craniofacial morphology on the upper airway dimensions. Angle Orthodontist (2015), Vol 85 - 5.

20. ***Jayan B, Kadu A.*** Airway-focused orthodontics. J Indian Orthod Soc 2018;52:S23-8.

21. ***Jaipal Singh Tarkar et al.,*** An Evaluation of Upper and Lower Pharyngeal Airway Width, Tongue Posture and Hyoid Bone Position. Journal of Clinical and Diagnostic Research. 2016 Jan, Vol-10(1): ZC79-ZC83.

22. ***Jee Hun Kim.*** The evaluation of hyoid bone in different skeletal malocclusions and growth patterns in Indian population. Int. J. Adv. Res. 2016- 4(9), 876-887

23. ***Jose NP, Shetty S, Mogra S, Shetty VS, Rangarajan S, Mary L.*** Evaluation of hyoid bone position and its correlation with pharyngeal airway space in different types of skeletal malocclusion. Contemp Clin Dent. 2014; 5(2):187–189.

24. ***Kaur, et al***. Reliability of lateral cephalogram and computed tomography for assessment of airway space. Niger J Clin Pract 2014; 17:629-36.

25. ***Kumar S, Arshad F, Nahin J, Lokesh NK, Riyaz K.*** Comparison of the changes in hyoid bone position in subjects with normodivergent and hyperdivergent growth patterns: A cephalometric study. APOS Trends Orthod 2017;7:224-9.

26. ***Laxmi et al.*** Importance of cephalographs in diagnosis of patients with sleep apnea. Contemp Clin Dent 2015;6:S221-6.

27. ***Machado Júnior, A. J. & Crespo, A. N.*** Cephalometric evaluation of the airway space and hyoid bone in children with atypical deglutition: correlations study. Int. J. Morphol., 30(1):341-346, 2012.

28. ***Mani P, Muthukumar K, Krishnan P, Senthil Kumar K P***. Upper and lower pharyngeal airway space in West-Tamil Nadu population. J Pharm Bioall Sci 2015;7, Suppl S2:539-42

29. ***Maria Julia Pereira Coelho Ferraz et al***. Cephalometric appraisal of the hyoid triangle in Brazilian people. Braz J Oral Sci. April-June 2006 -Vol. 5 – Measurements. Am. J of Ortho. Nov 2010.

30. ***Matthew Ball; Devang Padalia.*** StatPearls [Internet]. StatPearls Publishing; Treasure Island (FL): Feb 24, 2019. Anatomy, Head and Neck, Cervical, Respiratory, Larynx, and Cricoarytenoid.

31. ***Mohammed Amayeri et al.*** The Position of Hyoid bone in different Facial patterns: a Lateral Cephalometric study. Euro. Sci. Journal., May (2014) vol.10, No.15.

32. ***Mortazavi et al.*** Hyoid bone position in different facial skeletal patterns. J Clin Exp Dent. 2018;10(4):e346-51.

33. ***Neelapu et al.*** Craniofacial and upper airway morphology in adult obstructive sleep apnea patients: a systematic review and meta-analysis of cephalometric studies, Sleep Medicine Reviews (2016).

34. ***Nejaim et al.*** Evaluation of pharyngeal space and its correlation with mandible and hyoid bone in patients with different skeletal classes and facial types. Am J Orthod Dentofacial Orthop 2018;153:825-33.

35. ***Nuvusetty B, Peddu R, Prakash AS, Kalyani M, Devikanth L, Chadalawada D.*** Assessment of changes in pharyngeal airway size and hyoid bone position following orthodontic treatment of Class I bimaxillary dentoalveolar protrusion. J Indian Orthod Soc 2016;50:215-21.

36. ***Ruchengiz Efendiyevaa et al.*** Pharyngeal airway space, hyoid bone position, and head posture after bimaxillary orthognathic surgery in Class III patients Long-term evaluation. Angle Orthodontist, Vol 84, No 5, 2014.

37. ***SA Ara, Mujahid F, Patil BM.*** Role of dental radiologists in diagnosis of patients with high risk of obstructive sleep apnea using lateral cephalogram: A case–control study. Indian J Dent Sci 2019;11:36-41.
38. ***Sanaz Soheilifar and Mohammad Ali Momeni.*** Cephalometric Comparison of Position of the Hyoid Bone in Class I and Class II Patients. Iran J Ortho. 2017 March; 12(1):e6500.
39. ***Shastri, Dipti et al.*** "Cephalometric norms for the upper airway in a healthy North Indian population." Contemporary clinical dentistry (2015), vol. 6: 183-8.
40. ***Sheng CM, Lin LH, Su Y, Tsai HH.*** Developmental changes in pharyngeal airway depth and hyoid bone position from childhood to young adulthood. Angle Orthod 2009;79:484-90.
41. ***Shilpi S, Mathew S, Sagarkar R, Naidu M.*** Relationship of oropharynx to craniofacial morphology in skeletal Class II patients. J Indian Orthod Soc 2016;50:155-61.
42. ***Silva VG, Pinheiro LAM, Silveira PL, Duarte ASM, Faria AC, Carvalho EGB, et al.*** Correlation between cephalometric data and severity of sleep apnea. Braz J Otorhinolaryngol. 2014;80:191-5.
43. ***Sivakumar et al.,*** Assessment of hyoid bone position among different skeletal patterns, Orthod. Waves (2017).
44. ***Soonshin Hwang et al.*** Changes of Hyoid, Tongue and Pharyngeal Airway after Mandibular Setback Surgery by Intraoral Vertical Ramus Osteotomy. Angle Orthodontist, Vol 80, No 2, 2010.

45. ***Sprenger et al.*** A retrospective cephalometric study on upper airway spaces in different facial types. Progress in Orthodontics (2017) 18:25.

46. ***Sukniyom P, Viteporn S*** .Pharyngeal Airway Changes Following Extraction versus Non-extraction Treatments of Class II Division 1 Growing Patients. Int J Oral Dent Health (2019) 5:094.

47. ***T. Muto, A. Yamazaki, S. Takeda:*** A cephalometric evaluation of the pharyngeal airway space in patients with mandibular retrognathia and prognathia, and normal subjects. Int. J. Oral Maxillofac. Surg. 2008; 37: 228–231.

48. ***Un Bong Baik et al.*** Relationship between Cephalometric Characteristics and Obstructive Sites in Obstructive Sleep Apnea Syndrome. Angle Orthod 2002;72:124–134.

49. ***Vadher V, Sudheer Kumar CH, Khare V, Nande RS, Sharma S, Jain V.*** Assessment of relation of orofacial structures with pharynx among males and females: A lateral cephalometric study. Contemp Clin Dent 2018;9:S354-7.

50. ***Valeria Parisella et al.*** Cephalometric evaluation of the hyoid triangle before and after maxillary rapid expansion in patients with skeletal class II, mixed dentition, and infantile swallowing. Annali di Stomatologia 2012; III (3/4): 95-99.

51. ***Verma et al.*** Cephalometric evaluation of hyoid bone position and pharyngeal spaces following treatment with Twin block appliance. J Orthodont Sci 2012;1:77-82.

52. ***Vijaylaxmi Mendigeri.*** Significance of hyoid bone and its position in orthodontics- a review. International Journal of Nursing Education & Research. 2015;1(1):1-5.

53. ***Wang et al.*** Changes of pharyngeal airway size and hyoid bone position following orthodontic treatment of Class I bimaxillary protrusion. Angle Orthodontist, Vol 82, No 1, 2012.

54. **Yu SH, Nahm DS, Baek SH.** Reliability of landmark identification on monitor-displayed lateral cephalometric images. Am J Orthod Dentofacial Orthop 2008;133:790.e1-6.

Annexure

Annexure – I

NASOPHARYNX

S.NO	AGE	SEX	C3-RGn	C3-H	H-RGn	H-H'	HP angle	AA - PNS	Dhoriz-H	dvert - H	PH - BaN	HP - PP
1	17	F	44.2	51.4	55.8	63.5	363.5	7.3	24.4	41.4	307.6	218.4
2	26	F	55.2	57.9	69.8	64.9	356.5	13.2	62.3	32.8	277.2	230.5
3	27	M	52.3	53.6	60.1	56.3	358.8	8.3	60.9	25	104.4	216.8
4	24	F	53.7	55.9	66.8	62.2	186	13.4	46.2	34.1	272.8	116.3
5	23	F	64.5	63.2	77.9	70.9	354.1	15.6	69.4	12.5	283.8	129.7
6	22	F	63.9	66.8	71.7	67.7	357.5	18.2	65.1	22.5	286	228.6
7	20	M	58.9	62.6	67.7	63.3	315.9	16.5	61.7	29.7	286.2	189.3
8	23	M	68.7	73.5	84.3	79.3	311.3	13.8	80.1	27.7	274.7	302.4
9	21	M	68.1	76.8	85.1	80.8	316.6	17.2	77.7	18.7	313.6	254.7
10	18	M	67.2	79.1	80.9	86.8	310.8	15	84.5	16	266.1	256.4
11	22	M	56	64.8	79.1	78.9	180.9	16.7	78.1	18.9	275.3	103.1
12	16	M	54	58.6	76.2	71.7	316	10	68.6	5.2	298.2	237.5
13	21	M	53.8	63.2	71.4	69.4	315.7	14.8	66.3	6.1	314.6	120.5
14	28	M	64.5	74.4	88.7	90.5	316.5	19.9	81.8	5.9	283.7	108.7
15	25	F	56.7	64.2	69.4	67.2	313.1	12.7	68.4	2.6	299.2	279.9
16	21	F	48.6	58.4	67.2	61	140.6	10.6	64.3	13.9	317.4	123.5
17	25	M	64.3	75.7	80.2	77.4	314.4	8.5	76.3	13	309.3	115.7
18	19	M	52.8	63	71.3	67.5	313.8	9.7	71.6	8.9	285.6	293.1
19	20	M	56.7	60.6	67.9	64.3	309	17.6	63.1	14	284.5	108.5
20	26	M	60.8	71.8	86.5	65	295.5	12.7	75.5	11.7	204.1	98.7
21	23	M	69.2	79.1	82	80.8	278.5	14.2	80	12.1	284.8	210.2
22	21	M	61.5	69.4	84	85.4	328.8	18.9	80.1	17.9	326.7	122.6
23	24	F	72.1	84.7	88.6	86.9	298.3	14.5	82.1	11.2	298.2	303.4
24	21	F	54.4	57.2	67.1	60	306.5	9.2	62.1	8.6	300.2	275.3
25	17	F	56.1	60.5	70.3	62.9	312.3	10.4	66.4	6.7	313.7	270
26	24	F	55.7	62.4	67.3	63.9	292.5	5.5	62.9	0	306.3	250.6
27	22	F	55.2	61.9	71.2	64.5	290.9	13	64.8	7.5	285.2	339.5
28	20	F	44.7	54.5	67.2	59.3	278.6	11.4	69.3	9.5	286.7	306.5
29	19	F	47	56.7	70.2	65.9	298.9	13.7	64	7	289	297.6
30	24	F	43	51.9	63.6	61.2	270	10.2	57	6.2	267	289

OROPHARYNX

S.NO	AGE	SEX	C3-RGn	C3-H	H - RGn	H - H'	HP Angle	AA - PNS	dhoriz-H	dvert - H	PH - BaN	HP - PP
1	17	F	58	21.4	35.9	20.4	345.9	44.7	18.6	59.9	114.9	291.4
2	26	F	66.1	27.3	41.5	27.4	265.2	42	22.3	61.3	166.1	265.7
3	27	M	64.1	30.5	52.7	31.3	278	44	28	65.8	198.3	340.6
4	24	F	60.4	26.6	41.7	26	219.7	41.9	27	65.5	202.4	320
5	23	F	70.4	26	46	24.1	224.9	52.8	23	72.1	196.2	204.1
6	22	F	55.3	19.5	32.4	22	263.8	47.6	20.2	59.1	164.2	268.8
7	20	M	60	29.3	48	26.5	269.9	52.9	28	64.4	163.6	259.1
8	23	M	60.9	30	36.1	29.2	265.8	52.5	29	64.9	161.6	293.7
9	21	M	64.3	33.1	47.2	28.3	244	55.6	28.8	66	193.7	246.8
10	18	M	60.9	36.5	49.5	30	258.6	45.9	27.6	50.7	179.6	255.9
11	22	M	62.9	35.6	50.3	30.7	255.3	41.4	29.7	50.4	157.7	256.9
12	16	M	53.2	31.9	43.1	29.7	240.8	41.6	26.4	54.6	166	256.9
13	21	M	65.4	37	44	30.3	248.4	50.7	35	68.5	166.4	264.4
14	28	M	57.2	29.4	41.3	25.3	261.8	48.2	25.2	67.7	169	258.7
15	25	F	62.6	22.6	43.3	21.3	275.3	46	20.5	55.7	165.1	294.6
16	21	F	62.9	30.9	46.9	26.4	265.3	48.6	25.5	48.4	161.7	262.9
17	25	M	62.7	30.4	45.9	26.9	252.5	47.9	25.5	47.9	163.2	283
18	19	M	57.9	25.9	33.4	23.7	268.4	47.9	20.2	51.3	157.3	272.8
19	20	M	75.9	33.6	55.6	30.1	262.1	54.4	28.3	42.8	160.2	253.9
20	26	M	72.1	30.1	54.6	28.9	268.4	47.9	20.2	51.3	157.3	272.8
21	23	M	61.5	37	50.8	31.2	246	59.6	32.2	61.4	163.7	273.4
22	21	M	67.6	31.6	43.8	24.5	254.5	55.7	23.2	73.2	161.9	269.2
23	24	F	54.3	28.3	37.8	24	236.9	43.3	24.2	55.3	160.8	261.9
24	21	F	56.1	25.9	40.3	27.8	312.3	45.8	22.5	66.9	170.8	270
25	17	F	55.7	22.7	46.3	30.6	292.5	55.4	23.8	56.3	159.7	250.6
26	24	F	55.2	23.8	51.6	22.5	290.9	47.5	24.7	47.9	197.8	339.5
27	22	F	66.7	30.5	47.2	25.9	278.6	51.6	23.6	52.5	187.5	306.5
28	20	F	55.2	32.8	49.8	30.2	356.5	48.6	24.7	46.8	177.8	230.5
29	19	F	57.9	33.9	50	28.9	298.9	55	27.9	53	172.8	285
30	24	F	50	27.8	57	30.7	270	53.5	22.6	57.6	178	289

HYPOPHARYNX

S.NO	AGE	SEX	C3-RGn	C3-H	H - RGn	H - H'	HP Angle	AA - PNS	dhoriz-H	dvert - H	PH - BaN	HP - PP
1	17	F	14	9.6	10.1	13.6	269.9	59.7	22.3	71.4	270.9	268.6
2	26	F	18.8	9	12.7	11.2	270.4	59.1	19.5	69.8	284.7	273.8
3	27	M	18.6	10.3	11.8	16	258.3	60.2	28.7	63.9	278.5	264.6
4	24	F	14.9	11.1	12.3	16.6	272.2	73.5	30	63.5	285.2	271.6
5	23	F	9.8	8.7	5.5	13.4	258.5	57.1	24.7	62.8	284.9	268.9
6	22	F	21.7	18.1	16.4	19.9	275.8	67	25.8	74.8	282	267.3
7	20	M	23.8	14.2	15.8	22.5	265	73.7	27.7	81.2	264.3	284.3
8	23	M	27.4	11.4	19.3	22.8	272.4	70.6	28.7	64.8	270.4	287.7
9	21	M	19.9	10.9	11.4	20.8	245.2	69.5	37.6	81.9	284.7	264.3
10	18	M	14	5.2	4.4	14.7	265.5	2.1	30	63.7	285.5	270.8
11	22	M	23.4	14.4	16.2	22.7	265.5	63	33.5	70.8	280.9	267.4
12	16	M	19.5	10.9	11.7	18.6	254.3	57.6	26.5	68	280.7	258.3
13	21	M	26.3	11.8	15.1	26	246.3	71.8	30.1	85.9	267.9	257.6
14	28	M	23.9	11.2	14.4	19.6	257	67.1	28.9	73.5	272.3	260.2
15	25	F	25.8	16.8	20.8	23	261.1	65	21.9	70.6	279.3	257.6
16	21	F	24.3	10.1	15.3	16.9	274.9	58.7	17.7	68.5	281	271.8
17	25	M	23.3	9.9	12.8	20.6	253.7	81.7	29.2	73.3	279.2	266
18	19	M	19.3	12.3	16.2	18.5	258.7	54.3	23	58.8	262.1	240.7
19	20	M	13.6	8.5	10	14.9	236.9	67.1	35	74	269.7	250.1
20	26	M	29.1	15.8	18.6	24	262.9	78.6	40.1	83	268.3	256.7
21	23	M	5.7	10.7	11.2	23.8	241.3	51.3	31	69.1	272.6	264.1
22	21	M	30.2	12.8	19.3	26.8	261.1	74.2	36.1	79.1	260.2	280.1
23	24	F	11.8	9.2	9.6	14.5	247.7	55.6	25.4	60.2	274.1	255.5
24	21	F	23	10	15	22	260	67.9	30.9	57	287	265
25	17	F	17	7.6	13.6	20.7	245.6	59	35	67.8	267.8	254
26	24	F	18.7	9.7	14	21	237.5	73	23	56	279	261.8
27	22	F	21.7	11.4	11.8	18	246	57	27	65.4	267.9	259
28	20	F	25	10.6	17	13.7	250	67	31.7	67.4	285.3	279.5
29	19	F	17.9	5.7	12.8	12	276	48.9	27.8	71	275.3	237.9
30	24	F	19.8	10.9	16.7	11.8	240	55.8	29	69	261.9	245.8

Annexure – II

RAGAS DENTAL COLLEGE & HOSPITAL

(Unit of Ragas Educational Society)
Recognized by the Dental Council of India, New Delhi
Affiliated to The Tamilnadu Dr. M.G.R. Medical University, Chennai - 600 032

2/102, East Coast Road, Uthandi, Chennai - 600 119. INDIA
Tele : (044) 2453 0002 - 06. Principal (Dir) 2453 0001 Fax : (044) 24530009

TO WHOM SO EVER IT MAY CONCERN

Date: 20.12.2019

Place: Chennai

From

The Institutional Review Board

Ragas Dental College and Hospital

Uthandi, Chennai – 119

The Project titled **"PHARYNGEAL AIRWAY ANALYSIS IN RELATION TO POSITION OF HYOID BONE USING LATERAL CEPHALOMETRICS - A RETROSPECTIVE STUDY"**, submitted by **Dr.G.Jayashree** has been approved by the Institutional Review Board of Ragas Dental College and Hospital.

Dr.N.S .Azhagarasan,MDS
Member secretary,
The Institutional Review Board
Ragas Dental College and Hospital
Uthandi, Chennai – 119

Annexure – III

URKUND

Urkund Analysis Result

Analysed Document: 1. Front cover-merged.pdf (D62123375)
Submitted: 1/10/2020 8:50:00 AM
Submitted By: ${Xml.Encode(Model.Document.Submitter.Email)}
Significance: 8 %

Sources included in the report:

COMPUTED TOMOGRAPHIC EVALUATION OF PHARYNGEAL AIRWAY IN DIFFERENT DEGREE OF MANDIBUL AR FLARE – A RETROSPECTIVE STUDY.pdf (D46299724)
entire thesis.docx (D46263660)
JANETHA EWDIN THESIS.docx (D60766231)
Selva Final Full Thesis.pdf (D46341746)
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3545319/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5937958/
https://apospublications.com/comparison-of-the-changes-in-hyoid-bone-position-in-subjects-with-normodivergent-and-hyperdivergent-growth-patterns-a-cephalometric-study/
https://www.researchgate.net/publication/283331816_Comparison_of_pharyngeal_airway_dimension_tongue_and_hyoid_bone_position_based_on_ANB_angle
https://www.researchgate.net/publication/314270460_Pharyngeal_Airway_Space_and_Hyoid_Bone_Positioning_After_Different_Orthognathic_Surgeries_in_Skeletal_Class_II_Patients
https://www.researchgate.net/publication/260607675_Pharyngeal_airway_space_hyoid_bone_position_and_head_posture_after_bimaxillary_orthognathic_surgery_in_Class_III_patients_Long-term_evaluation
https://www.researchgate.net/publication/51525383_Changes_of_pharyngeal_airway_size_and_hyoid_bone_position_following_orthodontic_treatment_of_Class_I_bimaxillary_protrusion
https://www.researchgate.net/publication/230829942_Cephalometric_Evaluation_of_the_Airway_Space_and_Hyoid_Bone_in_Children_with_Atypical_Deglutition_Correlations_Study
https://www.unboundmedicine.com/medline/citation/21793712/Changes_of_pharyngeal_airway_size_and_hyoid_bone_position_following_orthodontic_treatment_of_Class_I_bimaxillary_protrusion_
https://www.semanticscholar.org/paper/Changes-of-pharyngeal-airway-size-and-hyoid-bone-of-Wang-Jia/b429abd367ab3bb8085c2c50afbde6f383287230
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4283530/
https://www.ncbi.nlm.nih.gov/books/NBK547693/
https://www.ncbi.nlm.nih.gov/pubmed/24987631