EVALUATION OF PHARYNGEAL AIRWAY SPACE MORPHOLOGY USING DIGITAL LATERAL CEPHALOGRAM IN ADULT POPULATION

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In the partial fulfillment of the requirement for the degree of

Master of Dental Surgery

in

Oral Medicine And Radiology

by

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BATCH 2020-2023

DECLARATION BY THE CANDIDATE

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-ALFRED NORTH WHITEHEAD

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Dr. RIBHU GANGULY

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LIST OF ABBREVIATIONS

BBDCODS	Babu Banarasi Das College of Dental Sciences
BBDU	Babu Banarasi Das University
OMR	Oral Medicine and Radiology
UAS	Upper airway space
OSA	Obstructive sleep apnea
PSG	Polysomnography
CT	Computed tomography
CBCT	Cone-beam computed tomography
OSAS	Obstructive sleep apnea syndrome
PAS	Pharyngeal airspace
NHP	Natural head position
SPAS	Superior posterior airway space
MAS	Middle airway space
IAS	Inferior airway space
VAL	Vertical airway length
OSA	Obstructive sleep apnea
AHI	Apnea hypopnea index
PSG	Polysomnography
NC	Neck circumference
BMI	Body mass index
LAFH	Lower anterior face height
MPA	Mandibular plane angle

ABSTRACT

INTRODUCTION

The relative growth and size of the soft tissues around the dentofacial bone are the primary determinants of pharyngeal space size. There have been studies showing craniofacial involvement in upper airway morphology and also a predisposing factor in any kind of obstruction to the airway. Lateral cephalometric radiographs, used in an attempt to identify morphological parameters can be beneficial. Thus, evaluation of pharyngeal airway space with the help of lateral cephalogram can be incorporated as a necessary measure to complete the overall craniofacial assessment.

AIM

To evaluate the pharyngeal airway space morphology using digital lateral cephalogram among adult population.

OBJECTIVES

1. To assess the pharyngeal airway space in digital lateral cephalogram for both male and female healthy individuals.
2. To compare the differences in pharyngeal airway spaces in digital lateral cephalogram between males and females.
3. To evaluate all the study population using STOPBANG questionnaire.
4. To assess the effectiveness of Digital Lateral Cephalogram and STOPBANG questionnaire as the predictor for diagnosis of Obstructive sleep apnea

MATERIALS AND METHOD

In the present study 200 patients (100 males and 100 females) with age range of 20 – 60 years were enrolled according to the inclusion and exclusion criteria. Routine clinical examination was done along with STOPBANG Questionnaire screening. Digital lateral cephalograms were taken of all the enrolled patients for the pharyngeal

airway space analysis. All the data had been collected, tabulated and was subjected to statistical analysis.

RESULTS

The results of the present study revealed a strong positive correlation between the overall score of STOPBANG and the age of the study subjects but a weak positive correlation was found with the gender, indicating advancing age and male gender as significant risk factors for OSA. A Very Strong inverse correlation was discovered between the total STOPBANG score and the width of the nasopharynx, oropharynx, and hypopharynx along with a significantly positive and strong correlation with the width of the hyoid bone and the third cervical vertebra.

CONCLUSION

The findings of the present study clearly indicated the male risk factor and the changes in morphology of the pharyngeal airway space as the predisposing factor towards the development of OSA, and are an important addition to a growing body of research that challenges the emerging standard of knowledge for this kind of study. A promising result was obtained from our study which emphasizes the importance of lateral cephalograms and adoption of STOPBANG Questionnaire in the screening of patients susceptible to Obstructive sleep apnea.

KEYWORDS – Pharyngeal airway space, Lateral Cephalogram, STOPBANG Questionnaire, Obstructive sleep apnea.

INTRODUCTION

The practice of dentistry has witnessed a paradigm shift not only in providing standard dental care but also in diagnosing diseases that inauspiciously affect a patient's general health. Dental surgeons need to be aware of a wide range of medical conditions to make appropriate medical and lifestyle modifications to improve a patient's prognosis and overall health in general.

The key to successful patient management is performing a thorough evaluation. Normal respiration is dependent on the sufficient anatomical dimensions of the airway. There have been studies showing craniofacial involvement in upper airway morphology and also a predisposing factor in any kind of obstruction to the airway. Thus, evaluation of pharyngeal airway space can be incorporated as a necessary measure to complete the overall craniofacial assessment.

The pharyngeal airway is an anatomical region comprised of the nasopharynx, oropharynx, and laryngeal pharynx. [1] It is well recognised that a functional airway is crucial for the appropriate development of craniofacial features. Several genetic and environmental variables determine the size and form of the human face and airway space. [2,3] According to the literature, the normal upper pharyngeal airway space is 15-20 mm and the lower pharyngeal airway space is 11-14 mm. [4] Certain skeletal characteristics, like retrusion of the maxilla or mandible and vertical maxillary excess, might induce a reduction in the anteroposterior dimension of the airway. In addition to allergies, environmental irritants, and infections, some other predisposing conditions can cause airway blockage. [5]

The relative growth and size of the soft tissues around the dentofacial bone are the primary determinants of pharyngeal space size. Changes in the dimensions of the

respiratory tract, such as constriction, can at times result in a decrease in airflow and breathing abnormalities, such as obstructive sleep apnea (OSA). [6]

Obstructive sleep apnea (OSA) is a breathing disease characterised by increased airway resistance during sleep, resulting in partial or full cessation of breathing. [7] Obesity, age, smoking, craniofacial and upper airway morphological anomalies are recognised as predisposing factors for OSA in adults. Current information indicates that OSA is related with smaller upper airway space size. [8] Other soft tissue features of the UAS, including as adenoids, soft palate length, and tongue dimensions, have also been indicated as relevant morphological factors in OSA. [9-11]

Various diagnostic tools, like as questionnaires (Berlin, STOP, STOPBANG) for the screening of OSA and radiographic modalities, are used to identify obstructive sleep apnea. Above all this polysomnography (PSG) is the gold standard test for the diagnosis of obstructive sleep apnea (OSA) [12], but given the high cost and limited availability of PSG infrastructure, skull radiography and cephalometric analysis can also be used to diagnose OSA.

Lateral cephalometry is a straightforward, well-standardized, and less expensive imaging technique that consists of a radiograph of the head and neck with a focus on the bony and soft tissue components. Using lateral cephalograms, computed tomography, and cone-beam computed tomography (CBCT) in healthy patients without pharyngeal or respiratory disorders, a number of studies have studied whether UAS size is connected with certain craniofacial traits. [13-15] While some studies have demonstrated that sagittal skeletal malocclusion impacts the size of the UAS, others have not. [15-18]

OSAS is a frequent form of sleep-disordered breathing characterized by repeated bouts of partial or total upper airway obstruction, which generates fragmented sleep

and associated symptoms. [19,20] It has been hypothesized that sleep position influences these occurrences, as people with the condition may experience more breathing problems when sleeping in a supine position. In addition, OSAS is associated with heart failure, ischemic heart disease, cardiac arrhythmias, and even sudden cardiac death. [21-23] Thus, OSA is a serious illness with major health-related effects and early screening of OSAS patients is crucial. One overnight polysomnography in a sleep laboratory is currently regarded as the diagnostic gold standard for OSAS. [24,25] Polysomnography is viewed as both time-consuming and expensive, despite the fact that its diagnostic superiority cannot be disputed. Consequently, this lateral cephalometric technique remains a useful preliminary screening tool for OSAS. Also, many sleep physicians have embraced intraoral appliances as noninvasive therapy techniques. [26-28]

Previous research demonstrated that postural effect should be considered when evaluating the shape of the upper airway, and investigations have demonstrated that there are distinguishable changes in upper airway structure between lateral cephalograms collected in two distinct positions, namely the upright and supine orientations. [29-31] However, to our knowledge, research using lateral cephalograms obtained in the upright position and analysis of the pharyngeal airway space in the adults and corelating it with OSA is limited. By assessing both the cephalometric data and the questionnaire-based results, the purpose of this study was to glean further information regarding the role of lateral cephalograms in the evaluation of the upper airway morphology. Hence, the current study determined the shape of the pharyngeal airway space on lateral cephalogram in conjunction with the STOPBANG questionnaire as a predictor of sleep apnea in the adult population.

AIM

To evaluate the pharyngeal airway space morphology using digital lateral cephalogram among adult population.

OBJECTIVES

1. To assess the pharyngeal airway space in digital lateral cephalogram for both male and female healthy individuals.
2. To compare the differences in pharyngeal airway spaces in digital lateral cephalogram between males and females.
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To assess the effectiveness of Digital Lateral Cephalogram and STOPBANG questionnaire as the predictor for diagnosis of Obstructive sleep apnea

REVIEW OF LITERATURE

Human beings are normally nasal breathers. The nasal and the oral cavities serve as pathways for respiratory airflow. The upper airway is composed of the nasopharynx, oropharynx and hypopharynx. A normal upper airway improves nasal breathing and is considered important in the growth and development of craniofacial structures. The pharyngeal airway plays a crucial role in breathing, swallowing and pronunciation. Changes in the dimensions of the respiratory tract that is, constriction can cause a decrease in airflow at times. Thus, evaluation of pharyngeal airway space can be incorporated as a necessary measure to complete the overall craniofacial assessment.

ANATOMY AND PHYSIOLOGY OF UPPER RESPIRATORY TRACT

EXTERNAL NOSE

The external nose is a pyramidal structure located in the midface, with its base resting on the facial bone and its tip jutting forward. The external nose is composed of two sets of paired nasal bones and two sets of paired cartilage. The upper lateral cartilages shape the middle section of the nose and provide support for the nasal valve beneath. The medial and lateral crura make up the butterfly-shaped lower lateral (alar) cartilages. The medial crus creates the columella, whereas the lateral crus shapes the nasal alae. These crura maintain the patency of nasal vestibule underneath them. The cartilage is maintained internally by the nasal septum. [32]

Small muscle groups covering the skeletal and cartilaginous tissue contribute to the external nose's function. Laterally extending from the alae, the nasalis muscle

depresses the nares. The anterior and posterior dilator naris, the depressor septinasi, and the levator labii superioris alaeque nasi all serve to expand the nostrils, hence decreasing nasal resistance. [33] During moments of increased nasal breathing, as in exercise, there is increase in the activity of the dilating muscles, which contributes to a wider nasal airway. [34]

VESTIBULE

The vestibule is the first portion of the respiratory tract to meet the external environment. The vestibule, unlike the remainder of the nasal cavity, is lined by stratified squamous epithelium. The nasal vestibule's epithelium transforms into pseudostratified columnar epithelium **(Fig 1)**. The vibrissae, which are thick hairs devoid of piloerector muscles, serve to filter out big particles. [35] The anterior nasal glands release serous mucus near the intersection of the squamous and respiratory epithelium. These secretions are atomized through the use of forced inspiration, such as sniffing. [36] The vestibule contains thermoreceptors that are absent from the respiratory epithelium-lined region of the nose cavity. This may result in alterations in nasal airway resistance upon stimulation. Warm air inhalation decreases nasal resistance, but cold air inhalation has the opposite effect. The vestibule is the most crucial region for detecting nasal airflow. [37]

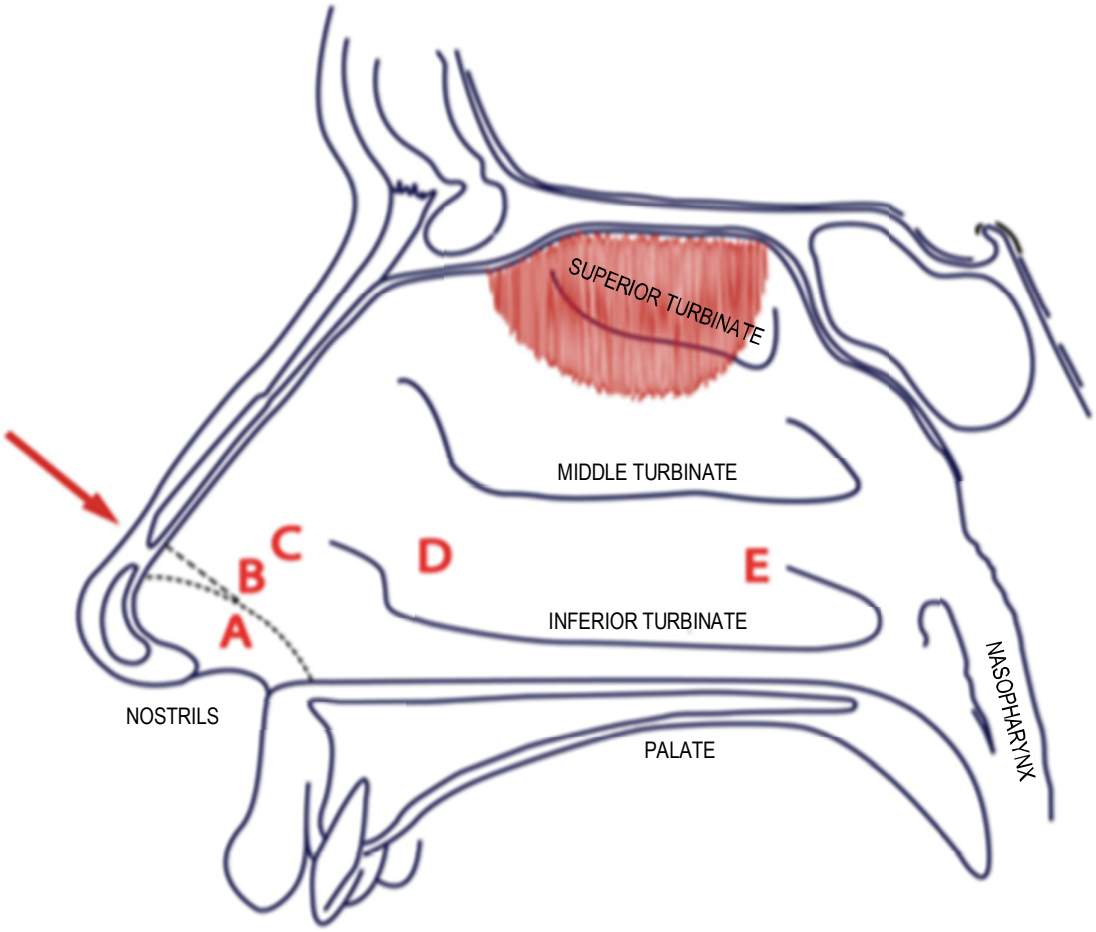


Figure 1 [38]. Lateral wall of nose, with hatched region representing olfactory area. Arrow points to area of nasal valve. Letters give epithelial type at specific locations: (A) skin in nostril; (B) squamous epithelium without microvilli; (C) transitional epithelium with short microvilli; (D) pseudostratified columnar epithelium with few ciliated cells; (E) pseudostratified columnar epithelium with many ciliated cells.

NASAL VALVE AND AIRFLOW

The nasal valve is directly posterior to the nasal vestibule. It is bordered laterally by the caudal end of the upper lateral cartilage, medially by the septum, and inferiorly by the pyriform aperture's lower rim. An enlarged portion of the septum in this location, known as the nasal septal swell body or septal turbinate, is regarded as part of the expansive vascular tissues of the nose. The nasal septal swell body mucosa is a highly glandular structure with a moderate proportion of venous sinusoids that appears to function in the region of the valve. [39,40]

The nasal valve has a cross-sectional size of 40 mm^2, while the nasal cavity has an area of 150 mm^2. [41] By contracting the dilator naris muscle, the cross-sectional area of the nasal valve can be expanded, resulting to an increase in airflow. [33] This is characterised clinically as nasal flaring during moments of respiratory effort. External nasal dilators, such as adhesive elastic strips put externally across the nasal valve area, have been demonstrated to dramatically increase the nasal valve's cross-sectional area and reduce congestion in normal patients. [42]

INSPIRATION

The nasal valve is responsible for between 50 and 75% of the overall resistance to inspired airflow from ambient air to the pulmonary alveoli. [43] The nasal valve propels inspired air upward past the middle turbinate, when the air's velocity approaches 18 m/s (gale force). The airflow takes a horizontal path through the major portion of the nasal cavity, where it slows to 2 to 3 m/s. The flow is greatest in proximity to the septal walls. [44]

EXPIRATION

The nasal valve may function as a respiratory brake during expiration in order to allow sufficient time for gas exchange at the alveoli. [45] Expiration lasts longer and has a more chaotic flow than inspiration. During expiration, the primary airflow is located in the middle airway and is slower than inspiration. Between inspiration and exhalation, vortices are detected. [46]

HEAT EXCHANGE AND HUMIDIFICATION

The design of the nasal cavity partitions nasal airflow into zones of high shear, which facilitates rapid heat transfer and humidification of the nasal mucosa. [47] At the nasal valve, laminar airflow is present, but this flow pattern is not maintained as air enters the nasal cavity. After air travels through the nasal valve, the laminar flow is replaced by turbulent flow, which is slower. This slow turbulent flow allows inspired air to have maximum contact with the warmer nasal mucosa; as a result, ambient air is warmed to approximately 34.8°C by the time it reaches the nasopharynx at resting respiration rates, with the greatest increase in temperature occurring in the anterior nasal segment, particularly in the nasal valve region. [48] This similar mechanism humidifies inspired air until the relative humidity in the nasopharynx approaches 100 percent. During the low-flow period of expiration in the nasal cavity, the now cooler and drier nasal mucosa regains heat and moisture lost during inspiration. Therefore, the lowest mucosal temperature can be recorded at the end of inspiration, whereas the highest mucosal temperature is obtained at the end of expiration. Cooling of expiratory air occurs predominantly in the inferior and middle turbinates. [49]

Normal nasal airflow is between 20 and 30 litres per minute; if larger volumes are required, oral breathing must be supplemented with nasal breathing. However, the net water loss increases by 42% when nasal breathing is replaced with oral breathing. [50] In general, physical activity generates a large increase in nasal volume, with length having a bigger impact on the degree of improvement than intensity. [51] This response is likely caused by sympathetic vasoconstriction.

During sleep, nasal airflow has a stimulant impact on breathing; breathing via the nose increases ventilation relative to mouth breathing. [52] Sleep apnea may be predisposed to develop by nasal obstruction. [53] The nasal resistance of children with adenotonsillar hypertrophy is a risk factor for sleep apnea. Normal persons will develop sleep apnea when a negative pressure is applied to the nose. Nasal constriction increases the effective CPAP–continuous positive airway pressure–in patients with sleep apnea. [54]

The airway geometry of the nasal cavity is complex, and variations in nasal cavity shape between people may result in distinct airflow distributions. Minor abnormalities in the region of the nasal valve, such as an anterior deviation of the nasal septum or mucosal oedema, might cause obstruction, but only significant abnormalities located more posteriorly can cause nasal airway obstruction. [55] During septorhinoplasty, alterations to the nasal valve, such as partial excision of the upper lateral cartilages or low lateral osteotomies beginning at the lower lateral region of the pyriform aperture, might weaken or narrow the nasal valve, causing nasal obstruction. Trimming the inferior turbinates affects the distribution of air to the olfactory region and the airflow pattern through the nasal cavity. [56]

Physically distinct from the lower airway, the nasal airway should not be mentally separated from the latter because alterations in the nose affect the lower airway. There are several similarities between the epithelium lining and the immunological response. This is obvious clinically in children with reactive airway disease whose condition is worsened by rhinosinusitis. Increased pulmonary resistance results from complete nasal blockage. [57]

NASAL CYCLE

In a healthy adult, total nasal airway resistance remains essentially constant, whereas the airflow of each nasal cavity fluctuates reciprocally (i.e., as the flow in one nasal cavity increases, the flow in the other decreases). This variation in airflow, known as the nasal cycle, is caused by alterations in the vascular engorgement of the turbinates and septal tuberculum. Because the total nasal airway resistance remains constant, the average human is oblivious of this cycling. During cycling, there is no change in the degree of water vapour saturation of the inhaled air. The nasal cycle's pacemaker is found in the hypothalamus. [58,59]

In adults, nasal cycling is believed to be controlled by the sympathetic nervous system via fibres of the deep petrosal nerve that join fibres of the greater superficial petrosal nerve (presynaptic parasympathetic fibres) to be distributed through branches of the sphenopalatine ganglion; cervical sympathetic blockade eliminates nasal cycling. [60] By boosting the vasoconstrictor tone, topical nasal decongestants increase nasal patency, hence reducing the congestion phase of the cycle. The complaint of alternating nasal blockage and acute upper respiratory tract infection demonstrates how the nasal cycle manifests during sickness. [61]

NASAL SEPTUM

The nasal septum separates the nasal cavity into two distinct compartments, hence increasing the overall mucosal surface area. It is composed of an anterior cartilaginous component that supports the nasal tip and a posterior bony portion created by the perpendicular plate of the ethmoid and the vomer.

Structural abnormalities of the septum contribute to internal nasal asymmetry, which in turn induces compensatory changes in the morphology of the turbinates, resulting in alterations in nasal airway resistance. [62] Age affects the proportion of nasal septal abnormalities. Approximately ninety percent of adult patients suffer from septal abnormalities, according to global research. In females, a straight septum is twice as common as in males. [63] Small anterior deviations at the level of the nasal valve are associated with considerable nasal airway blockage, but big posterior deviations may have no effect on airflow resistance. In addition, a septal abscess, surgical intervention, or Wegener granulomatosis can cause a weakening or collapse of the septal cartilage, which threatens the nasal valve and nasal airflow. [64]

TURBINATES

The turbinates are three or, in rare cases, four scroll-like extensions from the lateral nasal wall **(Figure 2)**. The lower two, known as the inferior and middle turbinates, are the most functionally significant. Each turbinate is composed of a skeletal framework covered with respiratory epithelium. Similar to the nasal septum, they help increase the mucosal surface area of the nasal cavity to between 100 and 200 cm^2. [44]

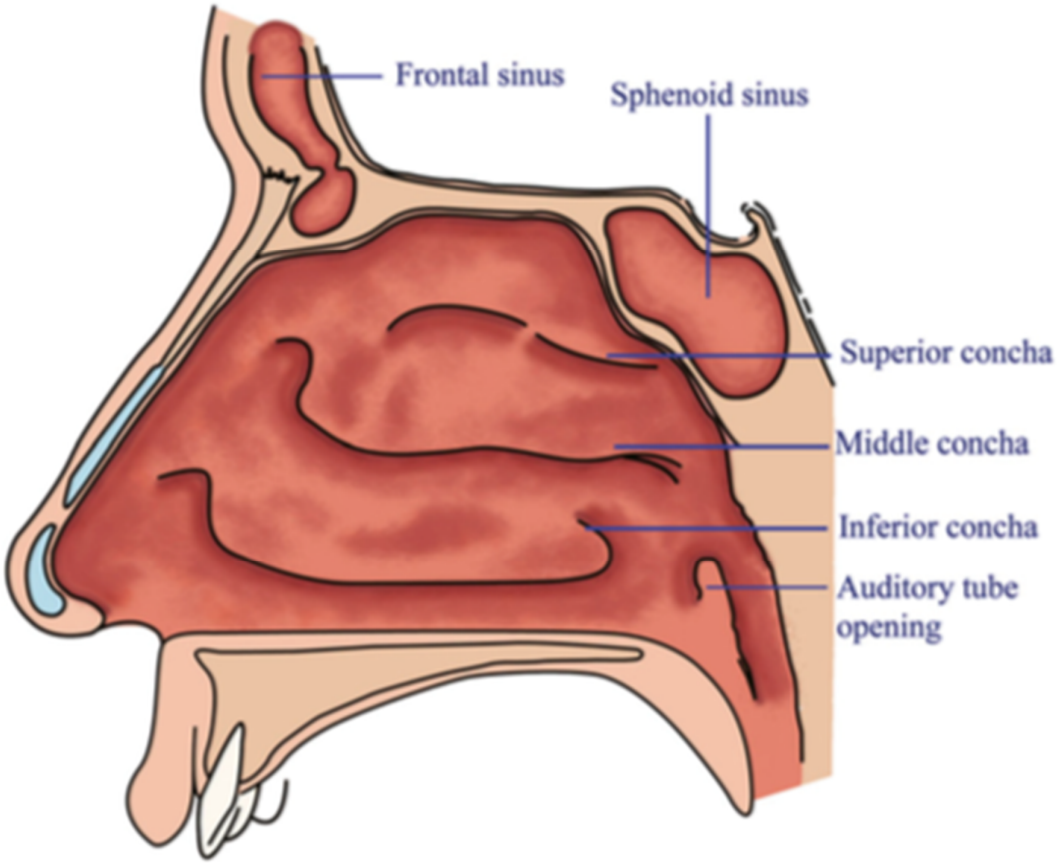


Figure 2 [65] View of the lateral wall of the nasal cavity.

The inferior turbinate plays an essential function in lung defence and the physiology of the nose. Trimming of the anterior section of the inferior turbinate can result in a decrease in total nasal airflow resistance [66] by widening the nasal valve; however, this should only be undertaken after investigating potential causes for its expansion. In inferior turbinate reduction surgery, in order to preserve turbinate function, one must take into account the fact that the area fraction of glands in the lateral mucosa significantly exceeds that of the medial and inferior mucosal layers, whereas the area fraction of venous sinusoids varies significantly, with the greatest variation occurring inferiorly. The cancellous central bony layer is composed of interlaced trabeculae and

contains the principal vascular supply of the turbinate; hence, it is recommended to keep the bone. [67]

HISTOLOGY

The nasal lining is composed of a mucosal epithelial layer and a submucosal layer. The mucosa is composed of pseudostratified columnar epithelium with goblet cells, ciliated and non-ciliated columnar cells with microvilli, and, occasionally, mast cells, eosinophils, and lymphocytes. [68] The cilia, which are protrusions measuring 5 mm in length, consist of a shaft coated by a cell membrane. The shaft, or axoneme, is composed of microtubules arranged as nine doublets around two singlets in the centre. Nexin connections connect neighbouring pairs of doublets, whereas spokes connect each doublet to the central tubules. Each doublet has two dynein arms containing ATPase, the enzyme that provides the energy for movement. [69] The secretions produced by epithelial goblet cells contribute to the mucous layer. The epithelial cells produce inflammatory chemicals and the secretory part of immunoglobulin IgA and form a protective barrier. [70]

A basement membrane separates the submucosa from the epithelial layer; it contains neurons, blood vessels, and nasal glands. The submucosal nasal glands are responsible for the majority of nasal secretions. The three primary types of nasal glands are the anterior serous glands, the seromucous glands, and the Bowman glands. The anterior nasal glands, which are located close to the nasal vestibule, may assist in hydrating the nasal mucosa as the inspired air distributes these thin secretions. The seromucous glands are responsible for the majority of nasal secretions. The majority of these glands are found in the front nasal cavity. Depending on the type of cell they contain, these glands either produce a serous or a mucous discharge. Bowman glands are

serous olfactory glands that contribute in smelling. Inflammatory mediators include histamine, bradykinin, prostaglandins, and cytokines are responsible for the pathophysiologic response to chemical or physical injury or antigen challenge. These mediators cause nasal symptoms through the following mechanisms: [32] direct action on blood vessels and submucosal glands resulting in increased glandular secretions, vasodilation, and increased vascular permeability; [33] sensorineural stimulation (maxillary and ophthalmic divisions of the fifth cranial nerve) resulting in glandular secretions and nasal symptoms such as sneezing, itching, pain, and pressure; [34] central nervous system effects leading to headache, fatigue, and mood changes and effects on bone marrow resulting in an increase in activity of bone marrow cells. Submucosa is devoid of lymphoid clumps. [71]

MUCOCILIARY CLEARANCE

Mucociliary transport is the mechanism through which secretions and trapped particles are removed from the nasal cavity. Mucous blanket and ciliated epithelial cells are the two most important components of this system.

MUCOUS BLANKET

The whole nasal cavity is covered by a 10 to 15 mm-thick mucous layer composed of secretions from goblet cells and submucosal glands and fluid transferred across the epithelium. [72] This mucous layer is composed of a sol phase, which is the periciliary watery layer, and a gel phase, which is the region nearest to the air. [73] **(Figure 3)**.

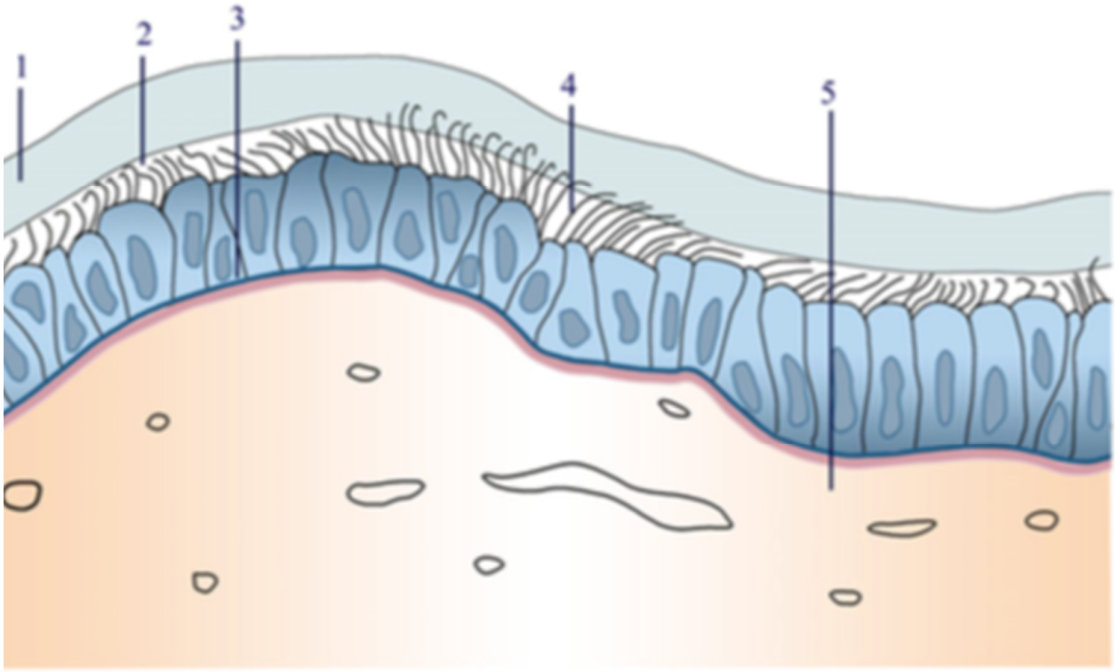


Figure 3 [73]. Two phases of nasal airway mucus layer. 1. Gel Phase, 2. Sol Phase, 3. Basement membrane, 4. Cilia, 5. Submucosal layer.

The nose is a highly effective filter. Larger particles are mostly filtered in the nasal valve region, whereas smaller particles are filtered by the nasal mucosa and delivered to the nasopharynx by ciliary movement. Intranasal particle deposition occurs during both inspiration and expiration. [74] Smaller particles and gases are poorly filtered; thus, they easily enter the lower respiratory tract. Therefore, surgical modifications to the nasal valve and turbinates may impair the nose's filtering capacity. Compared to adults, adolescents exhibit less efficient nasal filtration of big particles, particularly under situations of light exercise breathing. [75]

In addition to its ability to filter, the mucous blanket provides crucial defensive roles. It is the initial line of defence against viral and bacterial infection. IgA is the

predominant immunoglobulin in nasal secretions; it prevents pathogens from sticking to the nasal mucosa, hence preventing their penetration. [76] Additionally, the mucous blanket provides water for humidification.

Mucus production estimates range from 0.1 to 0.3 mg/kg per day. [77] Mucus is a secretion of goblet cells and submucosal glands. Mucus secretions are gel-like because to the presence of mucins, which are glycoproteins with a high molecular weight. Mucins are polymers composed of 80 to 90 percent carbohydrates, 20 percent protein, and 1 to 2 percent sulphate linked to oligosaccharide side chains. [78] Water binds to these side chains to produce a matrix that protects and lubricates the mucosal surfaces. Mucin genes (MUC genes) encode the protein backbones of mucins, at least 16 of which are expressed in the respiratory tract, while MUC5AC, MUC5B, and MUC2 are the three primary gel-forming mucins produced in the airway [73]. In addition to IgA, IgG, and IgE, mucus also contains histamine, albumin, bacteria, lactoferrin, lysozyme, ions, and cellular debris. [79]

The mucous layer advances posteriorly towards the nasopharynx, except in the region anterior to the inferior turbinate, where it moves anteriorly. Cilia may transport radiolabeled particles at an average rate of 6 mm/minute, with a range of 1 to 20 mm/minute; consequently, this transport can clear inhaled particles from the nasal cavity within 10 to 20 minutes. [80] Mucociliary transport times are increased with buffered hypertonic and normal saline irrigations, whereas they are lowered in the presence of nasal septal deviations and chronic sinusitis. Sniffing, sneezing, and blowing the nose aid in secretion removal. [81,82]

CILIA

The orientation of the cilia's basal feet determines the direction in which cilia beat. All cilia have a same orientation. Their beat consists of two strokes: an effector stroke in which the cilia straighten, contact the gel phase, and move mucus, and a recovery stroke in which the cilia bend and move in the watery sol phase. Unknown is how coordination and synchronisation of ciliary movement occurs. Location has no effect on the mean ciliary beat frequency. [83]

The results of studies on ciliary beat frequency in patients with chronic rhinosinusitis are contradictory, with some studies indicating impaired ciliary beat frequency in chronic rhinosinusitis [84] and others showing no difference in ciliary beat frequency between patients with chronic rhinosinusitis and healthy control subjects. Chronic sinusitis can decrease the number of ciliated cells and cause ultrastructural changes in the cilia, including compound cilia, peripheral and central microtubular abnormalities, and ciliary disorganisation. In addition, patients with chronic rhinosinusitis exhibit a diminished sinonasal ciliary response to external stimuli. [85,86]

Five minutes after administration of hypertonic saline, the ciliary beat frequency is dramatically accelerated. This impact is not observed one hour following dosing. [87] The nasal decongestant phenylephrine has a ciliostimulatory effect, whereas oxymetazoline does not influence nasal ciliary beat frequency in clinical concentrations. [88] Benzalkonium chloride, a common preservative in nasal sprays, increases ciliostasis and lowers mucociliary transport, but neither effect is clinically significant. Temperatures below 32°C or above 40°C result in a decrease in ciliary beating. [89,90]

In clinical manifestations of abnormalities in mucociliary transport, secretions collect along the floor of the nasal cavity. Total nasal blockage caused by entities such as adenoid hypertrophy or choanal atresia is the only other disorder that can produce this result. In immotile cilia syndrome, the ciliary structure is flawed, preventing movement. [91] By reducing the number of ciliated cells, common cold viruses can affect mucociliary transport for up to two weeks following infection. [92] In chronic sinusitis, the clearance of nasal secretions may be slowed by an increase in secretion viscosity. [93] Cystic fibrosis causes the production of abnormal mucus. At the surface of epithelial cells, sodium and chloride ion transport is changed, resulting in the creation of viscous, persistent mucus. Stasis of secretions can lead to the development of chronic rhinosinusitis in all of these conditions.

Mucociliary clearing operates under a vast array of environmental variables. The nose converts inhaled air to 100 percent relative humidity before it reaches the nasopharynx. The mucociliary clearance is unaffected despite the loss of heat and water during inspiration. The two components are partially restored after expiration.

NASAL VASCULATURE AND LYMPHATIC SYSTEM

Internal and external carotid circulations contribute to the nasal cavity's vascular supply. After traversing the orbit and the lamina papyracea, the anterior and posterior ethmoid arteries, which are branches of the ophthalmic artery, enter the nose. A terminal branch of the external carotid artery, the sphenopalatine artery enters the nose through the posterior lateral inferior wall. These vessels anastomose with branches of the facial artery in the septal portion of the vestibule, where a continuous arterial anastomotic triangle is composed of big, thin vessels, some of which are greater in diameter than the contributing arteries. [94] This region is clinically

significant since it is the most prevalent epistaxis site. The veins of the nasal cavity run parallel to the arteries and drain into the pterygoid and ocular venous plexi, with some of the venous drainage flowing intracranially into the cavernous sinus, providing a potential route for infection dissemination.

The perichondrial and periosteal arteries supply the subepithelial and glandular zones with their respective arteries. Before establishing a subepithelial network of fenestrated capillaries, they climb toward the surface, giving branches to cavernous plexi. It is considered the fenestrations that face the respiratory surface are primary source of fluid for humidification. [95]

Blood flow variations inside the cavernous sinusoids of the inferior turbinates, middle turbinates, and septum influence nasal airflow. Blood flow in this valveless plexus is controlled by the tone of the vessels in the arteriovenous anastomosis and venous drainage. With recumbency, elevated amounts of inspired carbon dioxide, and changes in inspired temperature, the size of the cavernous sinusoids also varies. The clinical manifestation of sinusoidal vascular congestion is nasal congestion. [96-98]

According to pharmacological investigations, blood arteries contain a, b, cholinergic, histamine, and hormone receptors. Alpha-adrenergic drugs cause vasoconstriction in the arteries and cavernous plexus. [99] The a1-adrenoceptors constrict the nasal arteries, while the a2-adrenoceptors contract nasal venous capacitance vessels. Phentolamine, an a-adrenergic antagonist, inhibits vasoconstriction caused by a. Vasodilation and an increase in watery discharges are caused by b-agonist delivery via the nasal route. [100]

Parasympathomimetics like methacholine produce watery discharges and vasodilation. [101] Ipratropium, an anticholinergic, inhibits methacholine's induction of watery discharges but not vasodilation. [102] Vasomotor rhinitis, a form of noninfectious, nonallergic rhinitis, causes nasal airway obstruction and profuse rhinorrhea, most likely as a result of an autonomic malfunction based on a paradoxical reaction of the nasal mucosa. [103]

When applied topically, histamine induces vasodilation, an increase in vascular permeability, an increase in glandular secretion, and sneezing or a tickling sensation. [104] Except for nasal congestion, which appears to be partially stopped by the addition of a histamine receptor type II (H2) antagonist [105], premedication with histamine receptor type I (H1) antagonists reduces the symptoms associated with histamine stimulation. Mucus secretion may be influenced by H3 receptors, which are believed to inhibit sympathetic activity.

The nasal vasculature appears to be four times more responsive than the heart to circulating adrenaline. [106] Changes in hormone levels during pregnancy can induce rhinitis, which resolves after delivery. The nasal vasculature is also affected by sexual arousal, hypothyroidism, and emotional strain. [107] Uncertain is the physiological involvement of adrenergic and cholinergic substances in the appropriate regulation of nasal secretions.

Lymphatic vessels of the nasal fossae drain toward the nasopharynx, whereas lymphatic vessels of the nasal vestibule drain toward the external nose and subsequently down the facial vessels to the submandibular lymph node group. Two major collecting trunks, one located high in the nasal vault and one situated inferiorly, drain into and around the eustachian tube orifice and into the first-echelon nodal

group, the lateral retropharyngeal lymph nodes. The location of these lymph nodes along the bodies of the vertebrae prevents palpation. This flow pattern explains the uncommon occurrence of palpable lymphadenopathy with rhinosinusitis. In 57% of instances, there is also transmural lymphatic outflow from the maxillary sinus to the nasal lymphatic arteries via bone gaps. [108]

PHARYNGEAL AIRWAYS SPACES

MORPHOLOGY

The pharynx connects the nasal cavity and mouth cavity to the larynx and oesophagus. Involved in the life-sustaining activities of breathing and swallowing, it is a member of both the respiratory and digestive systems. Air and food must travel through the pharynx independently to prevent air from entering the stomach and, more importantly, food from entering the airway. Pharynx is active during speech, coughing, vomiting, and gagging; as a result, its function is complex and needs the synchronisation of numerous muscles and nerves. [109]

The pharynx creates a funnel-shaped, vertical, 12-15 cm long fibromuscular tube. It extends from the base of the skull anteriorly to the cricoid cartilage level and posteriorly to the lower limit of the sixth cervical vertebra. [110] The pharynx is composed of three layers of soft tissue: mucosa, muscular membrane, and connective tissue. [12,13,16] It is anteriorly connected to the nasal cavity, oral cavity, and laryngeal entry. Laterally and posteriorly, the pharynx is bordered by connective tissue potential gaps (spatium parapharyngeum and retropharyngeum), enabling the pharynx to be easily pushed upwards while eating. [16] The breadth of the pharynx fluctuates continuously because it is determined by muscular tone. During sleep, muscular tone

is low, which dramatically diminishes the dimensions. This could result in snoring and sleep apnea. [15] The muscles can be divided into two layers, with the outermost three circular constrictors (Constrictor pharyngis superior, medius, and inferior) forming an incomplete ring anteriorly, and the innermost three vertically oriented muscles (m. Stylopharyngeus, m. Salpingopharyngeus, and m. Palatopharyngeus). The pharynx is composed of the nasopharynx, oropharynx, and hypopharynx (sometimes known as the laryngopharynx) [111] **(Figure 4)**.

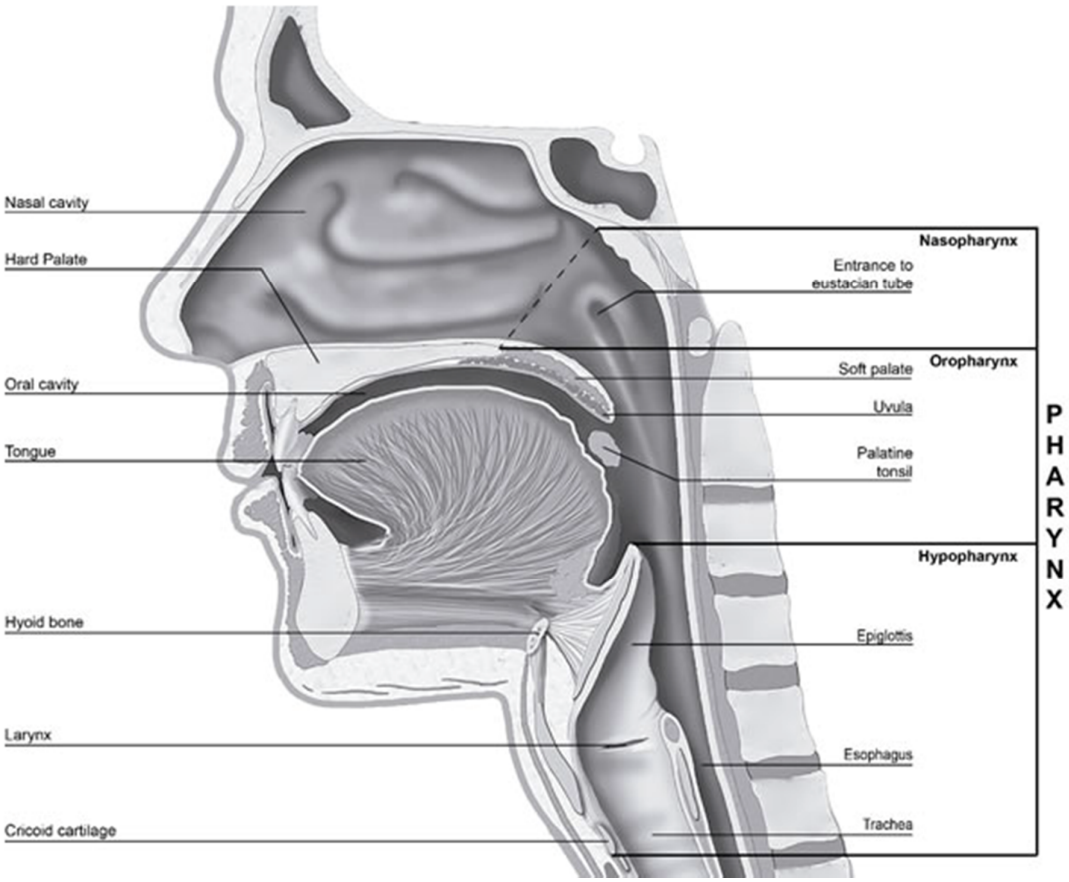


Figure 4 [112] Image illustrating the regions of the pharynx in sagittal plane.

Nasopharynx – The nasopharynx represents the most superior portion of the pharynx, bounded superiorly by the skull base and inferiorly by the soft palate. The

nasopharynx connects the nasal cavity to the oropharynx and contains the Eustachian tube openings and adenoids.

The **Boundary** of the nasopharynx comprises of the skull base, superiorly and the nasal cavity, anterior to it. Posteriorly it is bounded by the posterior pharyngeal wall and inferiorly by the soft palate. Laterally surrounded by the medial pterygoid plates and superior pharyngeal constrictor muscles (surrounded by visceral fascia). The anterior-posterior (A-P) diameter of the nasopharynx is approximately 2 cm, and the height is approximately 4 cm.

The **Contents** of the Nasopharynx include, the torus tubarius which is located immediately posterior to the opening of the eustachian tube. The eustachian tube opening is located at the posterolateral wall. The fossa of Rosenmuller which is located superior and posteriorly to the torus tubarius. And the adenoids (nasopharyngeal tonsils) which are in the roof and posterior wall of the nasopharynx.

The **Functions** include primarily, contributing to the voice resonance and production. Obstruction of the nasopharynx leads to voice changes (hyponasal). Muscles intrinsic to the nasopharynx control the opening of the eustachian tubes, which help control ventilation and equilibrium of atmospheric pressure between the middle ear cavity and nasopharynx. As inspired air is filtered and humidified within the nasal cavity, dust particles are trapped in nasal mucus and transported via the "mucociliary elevator," which beats towards the nasopharynx. From there, nasal debris drains to the oropharynx. The nasopharyngeal isthmus blocks the nasopharynx during swallowing. The nasopharynx is comparatively hard (except for the floor and soft palate) and, unlike the oropharynx and hypopharynx, cannot collapse due to muscular activity. [113]

Oropharynx - The Oropharynx, or the oral part of the pharynx, spreads from the soft palate to the upper margin of the epiglottis and has four walls (anterior, two lateral and posterior). Its anterior wall is defined by the pharyngeal aspect of the tongue. When the base of the tongue is depressed (e.g., during clinical examination) the anterior wall is visible through the opening called the oropharyngeal isthmus. This opening is bordered by the palatoglossal arch. The lateral walls of the oropharynx are marked by the palatopharyngeal arches and palatine tonsils. The posterior wall of the oropharynx extends from the body of the second to the upper part of the third cervical vertebrae (C2-C3). The oropharynx being the continuation of the oral-cavity and nasopharynx superiorly, and the larynx and hypopharynx inferiorly. It also forms part of the upper respiratory tract and the gastrointestinal tract.

The **Boundaries** comprises of the vertical plane defined by the circumvallate papillae, anterior tonsillar pillars, and border of hard and soft palate, anteriorly. Posteriorly it is bounded by the posterior pharyngeal wall. Superiorly, it is defined by the level of the soft palate free border and inferiorly by the level of the hyoid bone or tip of epiglottis. Laterally by the tonsillar fossae and pillars.

The **Contents** of Oropharynx include, base (posterior third) of tongue (including lingual tonsils), tonsillar complex (palatine tonsils, tonsillar fossae, and tonsillar pillars), soft palate (inferior surface and uvula) and pharyngeal wall (lateral and posterior).

The oropharynx is in connection with the oral cavity anteriorly via the anterior tonsillar pillars of the isthmus faucium. [114]

Hypopharynx - The hypopharynx, also referred to as the laryngopharynx, is the most caudal portion of the pharynx and is a crucial connection point through which food,

water, and air pass. Specifically, it refers to the point at which the pharynx divides anteriorly into the larynx and posteriorly into the esophagus. The act of swallowing, or deglutination, is a complex multistep process performed by several essential structures in the oral cavity, pharynx, and larynx. Swallowing ensures proper transport of food and water posteriorly into the esophagus at the level of the laryngopharynx. Although the laryngopharynx's primary physiologic function is as a cavity through which air, water, and food pass from the oral cavity to their respective destinations, it also contains structures that play an important role in speech.

The laryngopharynx is a clinically important anatomical location because of the high proportion of pharyngeal cancers that originate there. The laryngopharynx is also clinically relevant due to a disorder related to the retrograde flow of digestive stomach contents to the laryngopharynx, known as laryngopharyngeal reflux (LPR).

The laryngopharynx's position is inferior to the epiglottis and is bordered by the pharyngoepiglottic fold superiorly and the upper esophageal sphincter inferiorly. It refers to the portion of the pharynx where the cavity diverges anteriorly into the larynx and posteriorly into the esophagus. It contains three main structures: the posterior pharyngeal wall, pyriform sinuses, and the post-cricoid area. The pyriform sinuses, which play an essential role in speech, are two pear-shaped recesses located on either side of the laryngeal orifice. Medially to the pyriform sinuses lie the aryepiglottic folds. Thyroid cartilage lies lateral to the laryngopharynx.

The upper esophageal sphincter also referred to as the inferior pharyngeal sphincter, is made up of muscles that function in preventing the entry of air into the esophagus and reflux of gastric contents into the larynx and pharynx. It is made up mostly of cricopharyngeus muscle, along with thyropharyngeus muscle and cervical esophagus. The hypopharynx is responsible for both digestion and respiration. It is connected to

the oropharynx at the top, the laryngeal inlet at the front, and extends to the inferior border of the cricoid cartilage (at the level of the sixth cervical vertebra) where it narrows and connects to the oesophagus. [114]

FACTORS THAT AFFECT SIZE AND SHAPE

The pharynx is a fibromuscular tube that is supported by skeletal and soft tissue. Its configuration and dimensions are reliant not just on neighbouring anatomical structures, but also on patient-specific, dynamic factors. A correct evaluation of the upper airway must account for all variables. [115]

Using CBCT data on a large research population, **Schendel et al. (2009)** [116] discovered that as the airway grows, the total volume, length, area, and volume-to-length index all increase until age 20, then remain reasonably steady, and then begin to decrease dramatically beyond age 50.

Using 3D-CT, **Abramson et al. (2009)** [117] determined that the majority of upper airway growth occurred during the primary and permanent stages of dentition, which correlate to periods of high somatic growth. Moreover, they discovered that the airway of adults was broader and more elliptical than that of children.

Castro-Silva et al. (2015) [118] evaluated the pharyngeal airspace in three dimensions using preoperative CBCTs from patients with class I, II, and III skeletal malocclusions (PAS). They concluded that class III malocclusions had statistically larger mean volume and area. Those with class I had a greater volume than those with class II. Using CBCT, **Hong et al. (2011)** [119] analysed the pharyngeal airway capacity and cross-sectional area of individuals with skeletal class I and III malocclusions. They concluded that patients with class III malocclusions had a higher

upper pharyngeal airway volume than those with class I malocclusions, which corresponded to the mandible's anterior location. Moreover, individuals with class III malocclusions had a higher cross-sectional area in the lower pharyngeal airway than patients with class I malocclusions. Using CBCT data, **Dalmau et al. (2015)** [120] evaluated upper airway measurements across various sagittal (skeletal classes I, II, and II) and vertical (brachyfacial, mesofacial, and dolichofacial) craniofacial morphologies. Class III patients tended to have greater upper hyoid bone measurements than Class I and Class II patients. Compared to the brachyfacial and mesofacial pattern, the dolichofacial pattern tended to have smaller linear and area measurements at the level of the hard palate and the upper edge of the hyoid bone.

Brasil et al. (2016) [121] using CBCT examined the relationship between face profile, vertical patterns (brachyfacial, mesofacial, and dolichofacial), and sagittal (class II and III) skeletal types and upper airway dimensions. The cross-sectional area of the soft palate was bigger in individuals with class III, and the facial profile based on the proportions of the upper/medial/lower thirds permitted inferences on the pharyngeal airway capacity. However, there was no correlation between upper airway volume and sagittal skeletal type and vertical pattern. **Grauer et al. (2009)** [122] evaluated the variances in airway volume and shape amongst patients with distinct facial morphology using CBCT. The researchers determined that the anteroposterior skeletal type (Class I, II, or III) is associated to variance in upper airway size and form, whereas vertical skeletal patterns only influence upper airway shape. Using CBCT, **Celikoglu et al. (2014)** [123] examined pharyngeal airway volumes in adult patients with various vertical skeletal patterns and a clinically normal sagittal skeletal pattern (dental and skeletal class I relationship). They concluded that there are substantial differences: nasopharyngeal, oropharyngeal, and total airway volumes were lowest in

the high-angle group, whereas oropharyngeal and total airway volumes were greatest in the low-angle group. **Wang et al. (2014)** [124] wanted to investigate the relationship between the upper airway dimensions of skeletal class II patients with distinct vertical patterns (low, normal, and high angle) and their vertical patterns. Using CBCT imaging, they determined that the upper airway dimension was smaller in patients with a high angle compared to patients with other vertical skeletal patterns.

According to **Goncales et al. (2014)** [125], maxillomandibular abnormalities may impair the pharyngeal airway space, as well as the correction of these deformities with orthognathic surgery. The authors used pre- and postoperative CBCT data from patients undergoing orthognathic surgery (divided into 4 groups: only maxillary advancement; only mandibular advancement; maxillomandibular advancement; maxillary advancement and mandibular setback) to assess the pharyngeal airway and concluded that its size corresponds to the maxillomandibular movements performed during surgery and that bimaxillary advancements increased the sagittal and Recently, **Lee et al (2017)** [126] conducted a prospective clinical study using CBCT and sleep parameters to assess the changes in the pharyngeal airway in patients with skeletal class III malocclusions undergoing bimaxillary surgery (in the form of a simultaneous maxillomandibular setback) and correlate the prevalence of snoring and OSA as a measure of skeletal movement. They discovered that the maxillomandibular movement restricted the pharyngeal airway at the oropharynx, notably at the retropalatal and retroglossal level, hence lowering the total volume and producing snoring or sleep apnea in previously healthy patients with class III malocclusions. **Kim et al. (2013)** [127] utilised CBCT data from patients with mandibular prognathism who underwent bimaxillary surgery (maxilla advancement with clockwise rotation and mandible setback) to study positional changes of the hyoid bone and evaluate the

pharyngeal airway at various times, pre-operative, 2 and 6 months post-operative. Six months postoperatively, the procedure generated a more inferoposterior location of the hyoid bone and a reduction in the overall pharyngeal airway volume. The degree of decrease was correlated with changes in palatal plane inclination and hyoid bone location.

The hyoid bone is a highly mobile and robust bony anchor for a number of head and neck muscles and soft tissue components. Due to the fact that it is not articulated with other bones, the position of the hyoid bone varies with head posture, body position, and other physiologic conditions, and it moves in close combination with tongue action throughout various oral functions. An inferior hyoid bone is symptomatic of the shape, position, and tone of the tongue, which can contribute to obstruction of the upper airway. It is considered that the vertical location of the hyoid bone is a predictor of OSA. [128]

In general, nasal blockage, a long palate, a micro- and retrognathic mandible, a wide tongue, thick lateral pharyngeal walls, and/or pharyngeal fat all contribute to the collapse of the upper airway during sleep. [129] The most common airway constriction or increased collapsibility occurs at the oropharynx or base of the tongue in OSA patients. [126] In addition, it is believed that the structure of the upper airway is altered in OSA patients, being smaller laterally compared to normal individuals. [129] Compared to an airway that is originally rounded or extended in the anteroposterior plane, a laterally elliptical pharynx displays enhanced volume when dragged anteriorly by muscular action. To maintain patency, the lack of muscles on the lateral walls of the pharynx necessitates internal pressure on the airway. In apneic people, the posterior and lateral walls collapse. [130]

Several mechanisms functioning during wakefulness and sleep govern the patency of the upper airway, however these processes are weakened during sleep, leading to alterations in upper airway function and perhaps sleep-related breathing difficulties. Neuromuscular activity, craniofacial morphology, surrounding tissues, and the intrinsic features of the airway are the primary determinants. [128] Dynamic factors such as upstream resistance in the nasal cavity and throat, tissue compliance, and pharyngeal muscle activity are mechanical influences on airway size. The patency of the pharyngeal airway is also substantially impacted by static factors such as the location of the neck and jaw, and gravity.

The objective of the research conducted by **Sutthiprapaporn et al. (2008)** [131] was to examine the influence of pregnancy on oropharyngeal morphology in relation to postural alterations. The population sample was analysed in the upright position using cone beam computed tomography (CBCT) and in the supine position using conventional computed tomography (CT) to demonstrate that gravity causes movement in the oropharyngeal structures. The authors also discovered that the oropharynx's smallest area was greater in the upright position. The natural head position (NHP) varies between individuals and throughout time, as does physiologic posture. **Muto et al. (2002)** [132] investigated the relationship between cranio-cervical inclination and the pharyngeal airspace at various head postures in the same patients and discovered a link.

Using 3D imaging with CBCT, **Glupker et al. (2015)** [133] evaluated the volumetric differences in the upper airway between open and closed jaws. The volume of the oropharynx and the region of the soft palate decreased with jaw opening, whereas the volume of the nasopharynx grew. **Guijarro-Martnez et al. (2013)** [134] claimed that it

is essential to counsel the patient to prevent deglutition and movements, retain the jaw in a repeatable position, and breathe lightly throughout data collection.

CEPHALOMETRY

Cephalometry is a two-dimensional image of the patient's facial skeleton and soft tissue profile, viewed from the side. It is used mostly for analyzing craniofacial development and malocclusion. Additionally, soft tissue and craniofacial features associated with the upper airway can be analysed. In a two-dimensional perspective, the size of the upper airway craniofacial structures can be correctly quantified, and the angles between these structures can also be detected. Cephalometry is performed via standardized imaging techniques. For pharyngeal measurements, the individual should be sitting/standing with the head fixed to stabilize the posture, and the exposure should be performed toward the end of expiration.

The association between dentofacial morphology and risk for obstructive sleep apnea (OSA) and the influence of intraoral appliances on the airway have been investigated and evaluated using cephalometric investigations. It can also be used to evaluate the skeletal structure prior to orthognathic surgery and to determine the outcome of orthognathic surgery. [135]

LATERAL CEPHALOGRAM AND PATIENT POSITIONING

Lateral cephalometry is frequently utilised in clinical practise due to its relative ease, accessibility, low cost, and low radiation exposure.

Several different types of equipment are available for cephalometric radiography, either as separate units, or as additional attachments to panoramic units. In some

equipment the patients are seated, while in others they remain standing. Traditional equipment was designed to use indirect action radiographic film in an extraoral cassette as the image receptor. The advent of digital imaging, using phosphor plates and solid-state sensors, has seen the development of new dedicated digital equipment.

Several manufacturers have developed combined panoramic/cephalostat units utilizing specially designed solid-state sensors. An example is shown in **Fig. 5**. During the exposure, the X-ray beam and sensor move either horizontally or vertically to scan the patient, as shown in **Fig. 6**. The final image therefore takes a few seconds to build up. To ensure that the X-ray beam is the same shape as the CCD array in the sensor and that they are aligned exactly, the beam passes through a secondary collimator, which also moves throughout the exposure. [136]

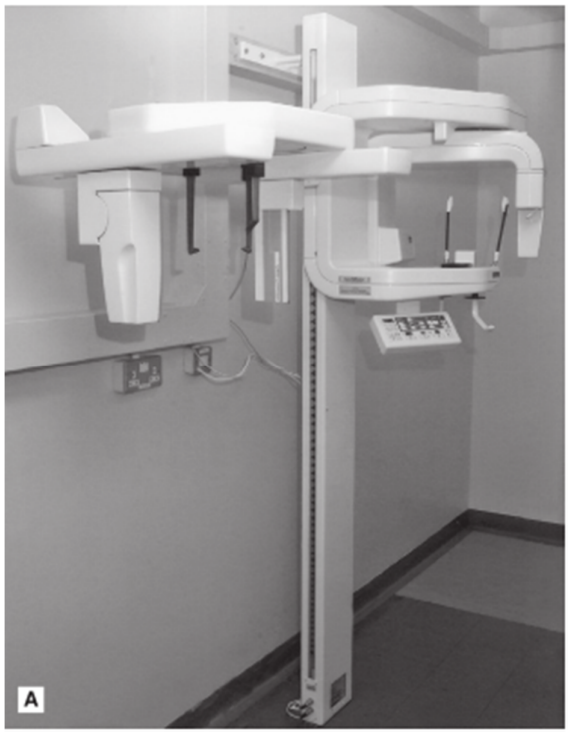


Figure 5 [136] - An example of a combined digital panoramic/cephalostat unit – the Planmeca Proline using the Dimax3 ® solid-state sensor.

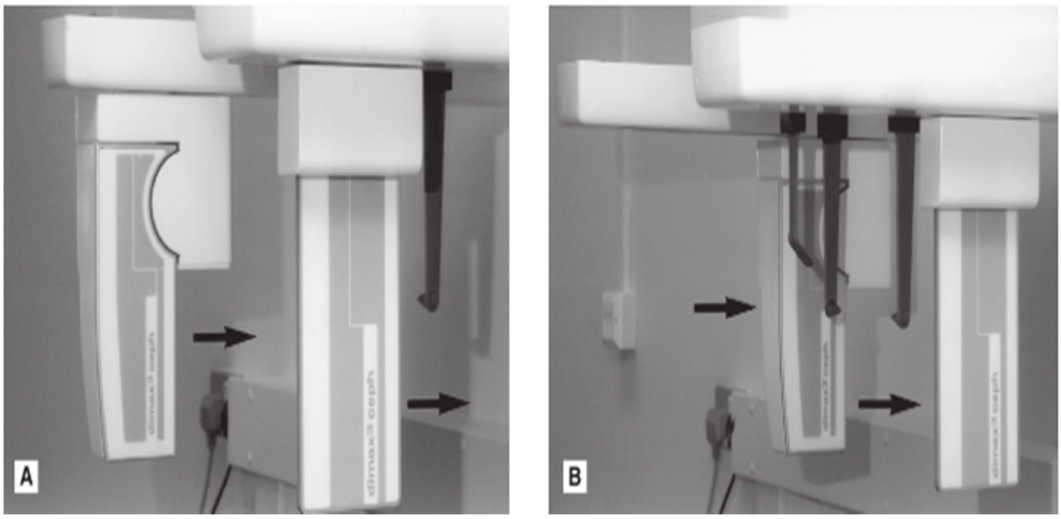


Figure 6 - Close-up of the Planmeca cephalostat. A At the start of the exposure and B at the end. This equipment is designed to scan the patient horizontally with the X-ray beam, secondary collimator and sensor moving horizontally throughout the exposure (arrowed).

Technique and positioning can be summarized as follows:

1. The patient is positioned within the cephalostat, with the sagittal plane of the head vertical and parallel to the image receptor and with the Frankfort plane horizontal. The teeth should generally be in maximum intercuspation.

2. The head is immobilized carefully within the apparatus with the plastic ear rods being inserted gradually into the external auditory meati.

3. The equipment is designed to ensure that when the patient is positioned correctly, the X-ray beam is horizontal and centred on the ear rods. **(Figure 7)**

Figure 7 - Patient positioned and immobilized within the cephalostat unit. Note the solid-state sensor (S) and the secondary collimator (SC).

A cephalometric trace can identify many characteristics that may suggest a constricted upper airway. Lateral cephalograms produce accurate linear measures [137], can assess the dimensions of the nasopharyngeal and retropalatal regions, but have not been shown to be accurate for measuring the airway at the back of the tongue. Nonetheless, this is a very reproducible test using the normal posture of the patient's head, given that it is conducted properly. [138] A 2013 meta-analysis on craniofacial morphology discovered a substantial association between a narrowed upper airway at the level of the pharynx (mostly adenoid hypertrophy) and paediatric sleep problems. [139, 140]

Figure 8 depicts the most often employed points and lines for assessing upper airway obstruction, as well as the reference airway diameters and diameters for persons with OSA [141]

McNamara claimed in 1984 that the airway is obstructed if the gap between the obstruction and the airway is less than 5 mm. Between the proximal points of the

posterior nasopharyngeal wall and the soft palate (Fig. 5B). **Fujioka et al. (1979)** [142] described the adenoidal-nasopharyngeal ratio (AN ratio) in 1979. This ratio compares the length of the line perpendicular to the sphenoid bone (A) by the thickest portion of the adenoids to the distance between the posterior nasal spine and the anterior edge of the sphenobasilar synchondrosis (N). AN <0.8 is regarded normal, while AN >0.8 is considered enlarged (Fig. 5D).

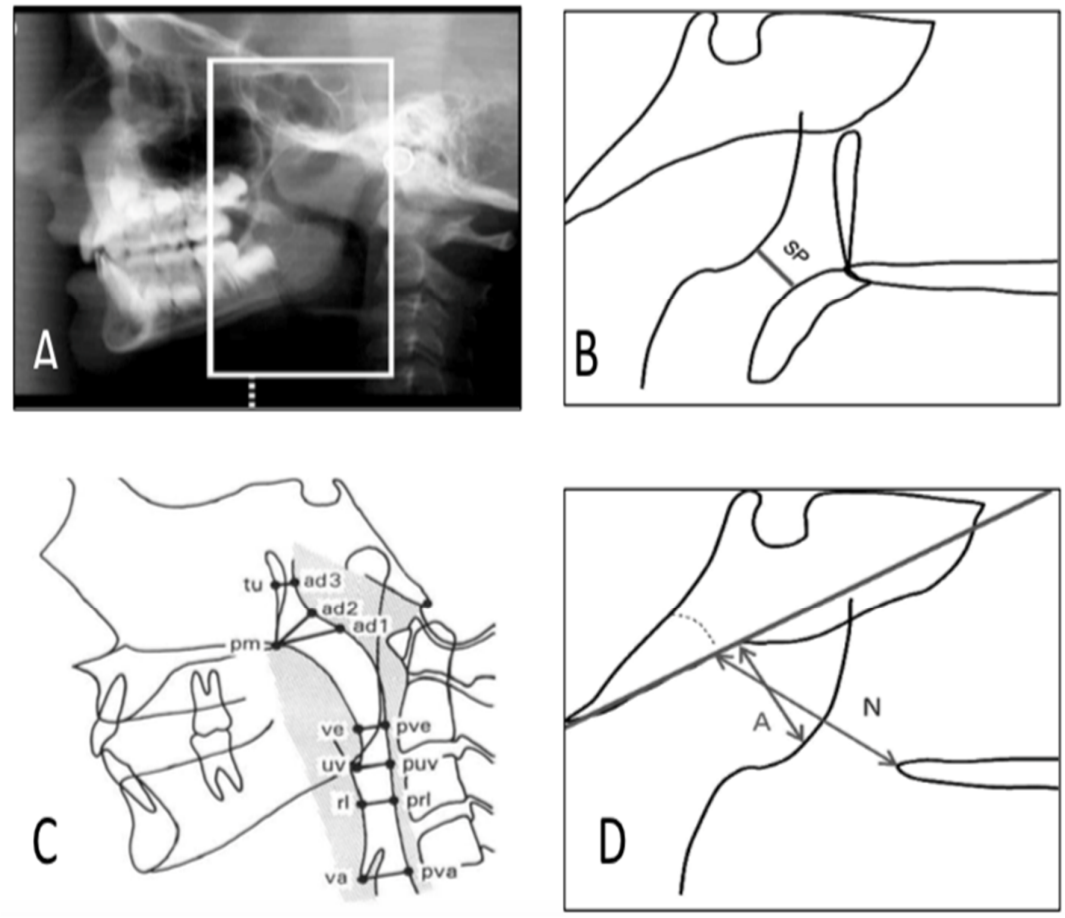


Figure 8 [141]: shows the points and lines most commonly used to assess upper airway obstruction, as well as the reference airway diameters and the diameters for individuals with OSAS

One of the most prevalent causes of upper airway obstruction is hypertrophic adenoids, which are characterised as a cluster of lymphoid tissues in the posterior wall of the nasopharynx that increase in size as immunological activity rises. Before planning orthodontic treatment, this region is typically evaluated in lateral cephalometry; consequently, lateral teleradiography is utilised as a lucrative and reproducible diagnostic approach that is simple to interpret when determining the size of the adenoids. With the advent of CBCT, orthodontists now have access to 3D pictures. Studies have attempted to establish a correlation between lateral cephalograms and CBCT in relation to the linear airway volumes, but no clear consensus has been reached.

The peak growth of adenoids occurs between 4 and 5 years of age, followed by another peak between 9 and 10 years of age, and then the size gradually decreases until 14 to 15 years of age. [142]

Dimensions of the pharyngeal airway can be evaluated as follows (Fig 9): the nasopharyngeal space above the palatal plane as represented by PNS-Ad1 and PNS-Ad2; the velopharyngeal space behind the soft palate as represented by superior posterior airway space (SPAS); and the glossopharyngeal space behind the tongue base described as middle airway space (MAS) and inferior airway space (IAS). [143]

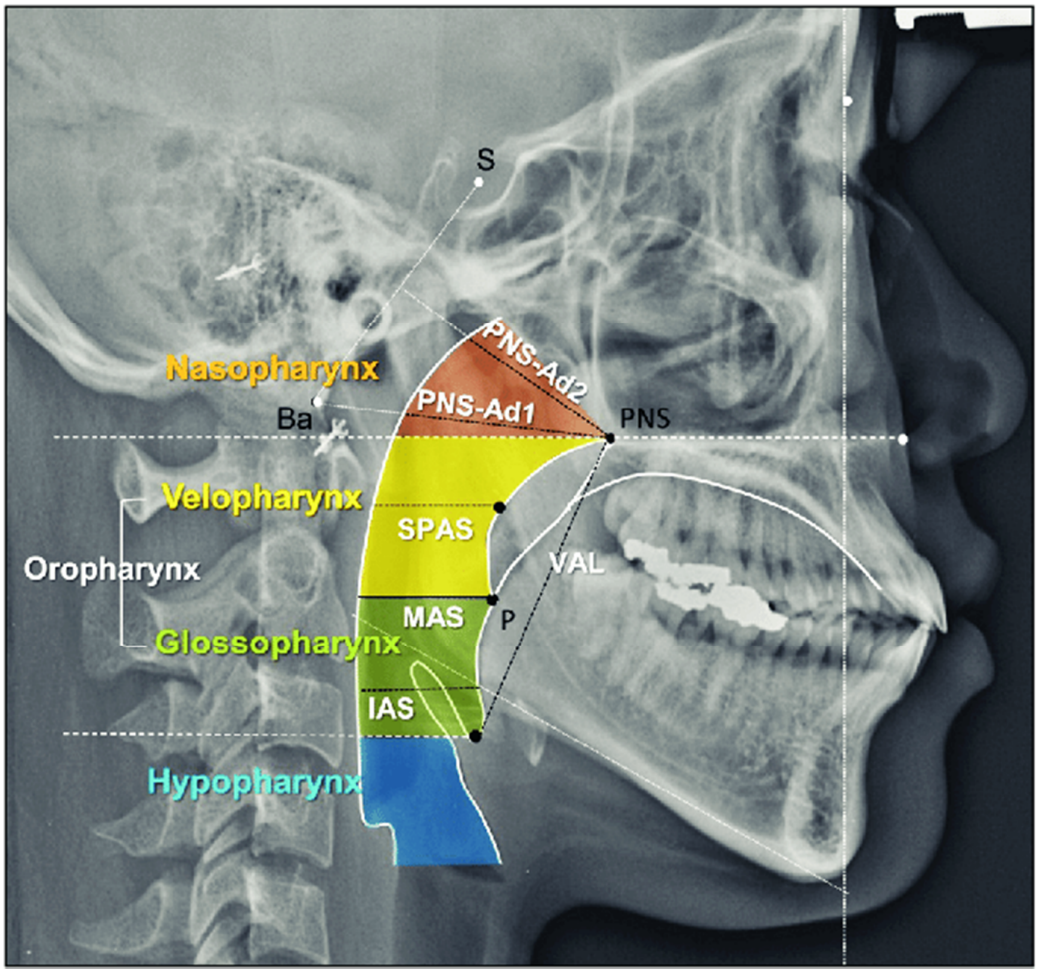


Figure 9 [143]. Cephalometric pharyngeal measurements to describe each pharyngeal airway section: PNS-Ad2 and PNS-Ad1 for the nasopharynx; superior posterior airway space (SPAS) for the velopharynx behind the soft pal- ate; middle airway space (MAS) and inferior airway space (IAS) for the glossopharynx behind the tongue base; and vertical airway length (VAL) for the pharyngeal airway length.

Factor affecting cephalometric imaging [144]

- Gender
- Race
- Method Related Factors
- Biological Factors
- Relapse
- Mandibular Center of Rotation

OBSTRUCTIVE SLEEP APNEA

Obstructive sleep apnea (OSA) is defined by episodes of full (apnea) or partial (hypopnea) closure of the upper airway, accompanied by a drop in oxygen saturation or awakening from sleep. [145] This disruption results in fragmented, restoratively ineffective sleep [146]. Additional symptoms include loud, noisy snoring, witnessed apneas during sleep, and excessive daytime tiredness. OSA has major effects on cardiovascular health, mental illness, quality of life, and driving safety. [147]

ETIOLOGY

Pharyngeal constriction and closure during sleep is a complex phenomenon, and several variables likely contribute to its aetiology. During sleep, sleep-related reduced ventilatory drive and neuromuscular as well as anatomic risk factors are anticipated to play a substantial role in upper airway blockage. [145] Large neck circumference, soft tissue, bone, or arteries are anatomic variables that induce pharyngeal constriction. [147] Several of these structures can cause an increase in the surrounding pressure of the upper airway, resulting in pharyngeal collapsibility and/or inadequate space to accept airflow in a section of the upper airway during sleep. [148, 149] In addition, the

muscular tone of the upper airway plays a role, as decreased tone results in repeated whole or partial airway collapse. Obesity, male sex, and growing age are the most common causes of OSA in adults. Adjusting for BMI, the severity of OSA diminishes with age. [150]

EPIDEMIOLOGY

The deleterious effects of obstructive sleep apnea are widespread and significant. OSA (using the criterion of five or more occurrences per hour) affects almost one billion people worldwide, with 425 million adults aged 30-69 years suffering from moderate to severe OSA. [151] 25-30% of males and 9-17% of women fulfil the diagnostic criteria for obstructive sleep apnea in the United States. [152, 153] Hispanics, African Americans, and Asians have the highest prevalence. Additionally, prevalence rises with age, and as individuals reach 50 years or older, there are equal numbers of women and men with the illness. The increased prevalence of obstructive sleep apnea is associated with the rising rates of obesity, which range from 14 to 55 percent. [152] As some risk variables, including obesity and upper airway soft tissue structure, are genetically inherited, it has been stated that there is a genetic component. [154]

PATHOPHYSIOLOGY

Obstruction of the upper airway during sleep is frequently caused by negative collapsing pressure during inspiration; nevertheless, progressive expiratory narrowing in the retropalatal region plays a significant role. [155] The correlation between upper airway constriction and body mass index during sleep suggests that anatomical and neuromuscular factors contribute to airway obstruction. [156] Utilizing the concept of the pressure-flow relationship through collapsible tubes is helpful for comprehending

the OSA mechanisms. [157] In the aetiology section, additional information regarding risk factors is provided.

CLINICAL FEATURES OF OSA

Obstructive sleep apnea (OSA) manifests in various ways, from subtle intrusion into daily life that may be unrecognized by the patient and providers to profound sleepiness, snoring, witnessed apneas, and other classics, more recognizable symptoms. **(TABLE A)** Unfortunately, the former presentation is the clinical norm. Symptom severity often progresses over the years, **(TABLE B)** leading to delayed diagnosis and allowing time for the disease to adversely affect health. Even with increasing awareness of the serious adverse consequences of untreated sleep apnea on patient outcomes and healthcare utilization, epidemiologic studies suggest that OSA is underdiagnosed. As the obesity epidemic continues to increase, the prevalence of OSA will likely continue to rise. Clinicians should be familiar with the subtle and overt clinical manifestations of OSA to accurately identify patients at risk for the disease, order appropriate testing, and tailor therapy to the individual patient.

A substantial amount of evidence supports an association between OSA and several disorders. Healthcare providers should strongly consider the possibility of OSA in patients with these comorbidities, mainly when found with characteristic symptoms and physical exam findings of OSA. The evaluation of comorbidities, symptoms, and anatomy is not only essential when screening patients for OSA but also crucial concerning determining diagnostic testing and treatment modalities.

SYMPTOMS ASSOCIATED WITH OBSTRUCTIVE SLEEP APNEA	
NOCTURNAL	**DIURNAL**
Snoring	Excessive sleepiness
Witnessed apnoeas	Morning headaches
Choking at night	Depression/irritability
Nicturia	Memory loss
Insomnia	Decreased libido

TABLE A

CLINICAL FINDINGS OF OBSTRUCTIVE SLEEP APNEA
Obesity
Enlarged neck circumference
Crowded upper airway
Hypertension
Accentuated P2 heart sounds (pulmonary HTN)
Retrognathia/overjet
Nasal obstruction
Decreased oxygen saturation
S3 heart sound (CHF)
Lower extremity edema (heart failure)

TABLE B

HISTOPATHOLOGICAL CHANGES IN OSA

Obstructive sleep apnea (OSA) is characterized by repetitive episodes of upper airway occlusion during sleep and is usually associated with fragmentation of sleep, daytime sleepiness, and hypoxemia. It is well established that in apneic patients, the pharyngeal airway volume is smaller than that of normal subjects, and is associated with increased airway resistance.

Yet, the exact cause of OSA remains unclear, and controversy surrounds the pathogenesis of OSA, which has a multifactorial origin. Some theorized that changes in the neurologic control of the upper airway, and/or in the pharyngeal structure are responsible for this ailment. Several histopathologic studies were performed that used qualitative, quantitative, or morphometric measures to assess the composition and the pathologic features of the soft palate and uvula of patients with OSA.

The posterior portion of the soft palate and the uvula, consists of three layers: an external epithelium, an underlying thick lamina propria, and a central musculoglandular layer. The epithelial cover of the oral surface is made of a stratified, squamous, nonkeratinized type, whereas that of the nasopharynx has two different ones: a pseudostratified ciliated columnar respiratory type, which covers the anterior portion of the soft palate toward the choanae, and a squamous epithelium located posteriorly, resembling the oral side, except for its lower height and fewer layers. The lamina propria is composed of loose connective tissue containing blood vessels and nerves and traversed by the seromucous glands' excretory ducts. In addition, occasional aggregates of lymphoid tissue are found adjacent to the nasopharyngeal mucosa and represent mucosa-associated lymphoid tissue (MALT). As a rule, the oral side of the lamina propria is thicker than that of the nasopharynx. The central core, which forms the third layer of the soft palate, is built of muscles intermingled with

seromucous glands. The musculus uvulae are cradled by the underlying levator veli palatini muscle, and islands of fatty tissue are scattered among the muscle fibers. The secretory portion of the palatal glandular tissue is of a mixed type, containing mucous and serous acini. On H&E staining, mucous cells appear clear, whereas serous ones are stained dark.

In addition to pure mucous and serous acini, there are also "mixed acini" in which mucous cells predominate, and serous cells are merely displaced to the blind ends of the terminal portion or to saccular out pockets. The latter appears as dark-stained crescents (demilunes of Gianuzzi) surrounding the edges of the mucous cell tubules. There is a topographic distribution of glands in the soft palate, where mucous acini prevail along the oral side, whereas mixed glands, containing both mucous acini and serous elements, are found under the nasopharyngeal mucosa. In many sections, bulks of glandular tissue are surrounded by striated muscle fibers. This arrangement has functional significance as the contraction of palatal muscle squeezes saliva from glands to provide continuous lubrication of the oropharynx and to prevent dryness and surface irritation during deglutition and speech.

The most prevalent pathologic change in patients with OSA was vascular engorgement of the uvula **(Figure 10)** and the presence of Edema involving either the oral side of the uvula or its entire distal portion **(Figure 11)**

The area fraction occupied by the various tissue constituents of the distal portion of the soft palate and uvula in patients with mild, moderate, and severe OSA and in normal individuals it is similar to a great extent. It is observed that the connective tissue is greater in patients with moderate OSA than in those with severe OSA and control subjects. Vascular engorgement, fibrosis, Edema, inflammatory cell

infiltration, and dilated glandular ducts are observed in patients with OSA, implying that these pathologic changes probably reflect the sequela of airway obstruction.

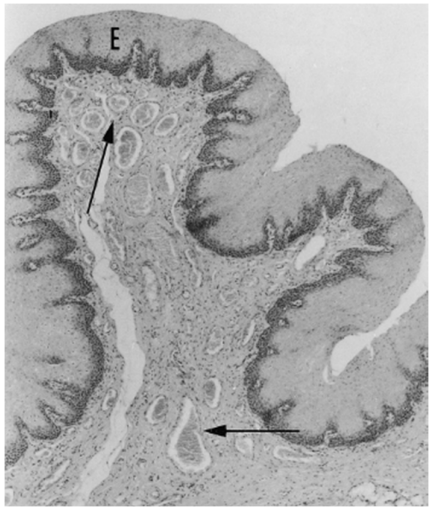


Figure 10 - Dilated and engorged blood vessels (arrows) surrounded by fibrotic stroma in the distal portion of the uvula of a patient with OSA. E = epithelium (H&E, original magnification x 100).

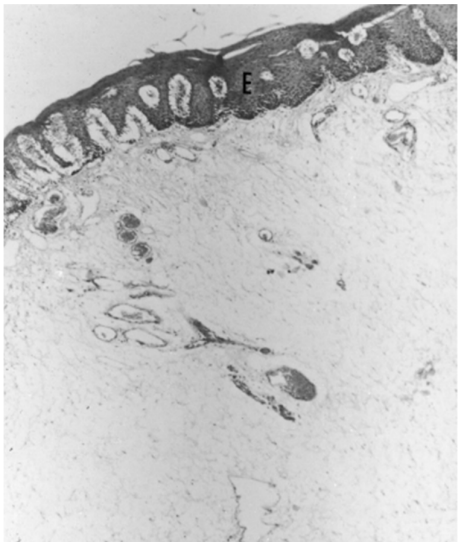


Figure 11 - Extensive edema along the oral side of the uvula of a patient with OSA. E = epithelium (H&E, original magnification x 100).

STUDIES RELATED TO PHARYNGEAL AIRWAY SPACE AND LATERAL CEPHALOGRAM

Maschtakow P.S.L et al., 2014 [4] conducted a study to identify craniofacial alterations in Obstructive Sleep Apnea patients in relation to individuals without clinical characteristics of the disease through the cephalometric analysis in Brazilian population. Using the z test and the student's t test, 55 lateral cephalograms of 26 OSA patients and 29 control subjects were evaluated. Using lateral cephalograms, it was possible to identify craniofacial changes in OSA patients due to a decrease in the dimensions of the upper airways and an increase in the length of the soft palate.

Ryu HH et al., 2015 [2] conducted a study to identify the correlations between lateral cephalometric parameters, which seemed to be related to OSA severities, and polysomnography (PSG) indices and to thus determine the cephalometric parameters reflecting OSA severity. By using lateral cephalography and PSG, a total of 140 subjects (122 men and 18 females) were assessed. Then, statistical analyses were performed on the cephalometric and PSG parameters. It was discovered that patients with OSA have a significant vertical airway length, a retrognathic mandible, a thick uvula, a large tongue, and a long mid-face length, and that they can be correctly assigned to the normal-to-mild and moderate-to-severe apnea hypopnea index (AHI) groups, concluding that lateral cephalometric radiography is an accessible and suitable tool for evaluation of craniofacial and soft tissue deformities in correlations with OSA.

Kulshrestha R et al., 2015 [5] conducted a cephalometric study to evaluate if the different body types and facial patterns have any effect on the dimensions of the pharyngeal airway space and tongue position. According to inclusion and exclusion criteria, 90 subjects were selected and categorized into three classes: ectomorphic, mesomorphic, and endomorphic, as well as FMA. There were substantial changes in soft palate inclination and upper pharyngeal wall between face growth patterns, however there was no difference in tongue position between groups.

Kaur S et al., 2015 [3] carried a study to find the interaction between craniofacial structures and pharyngeal airway space along with soft palate and tongue in patients with different anteroposterior skeletal patterns using lateral cephalogram. In order to determine the aetiology of OSA, the connection between upper airway and soft-tissue measures and neck circumference (NC) and body mass index (BMI) was determined. 45 patients were classified into three groups, and cephalometric analysis was conducted. In skeletal class II patients, the pharyngeal airway space was observed to be significantly diminished. The fat accumulation in the neck mediates the effects of obesity on obstructive sleep apnea through an increase in the size of the soft palate and tongue.

Scannone A et al., 2017 [6] conducted a study on 126 adults to identify features of craniofacial and dental phenotype associated with high suspicion of OSA. 77 girls and 49 males were evaluated using lateral cephalometry and dental cast models were created, which were then connected with the STOPBANG questionnaire-based analysis of these individuals. The outcome indicated the presence of skeletal

malocclusion in relation to suspected OSA, although no statistically significant differences in measures were discovered.

Sprenger R et al., 2017 [7] did a cephalometric study to evaluate the nasopharyngeal, oropharyngeal, and hypopharyngeal airway spaces variations according to the craniofacial growth pattern, by comparing different facial types in angle's Class I individuals. According to Tweed Angular Measurements, 45 lateral teleradiographs were utilized and categorized into 3 groups. The Kruskal-Wallis and ANOVA tests were utilized. The measurement of the median posterior-palatal space revealed a statistically significant difference between the groups, leading to the conclusion that persons with dolichofacial pattern have a smaller median posterior-palatal space measurement in the oropharynx region.

Kumar, A et al., 2017 [158] taken a total of 30 adult female patients with skeletal Class I jaw relationship were included in the study. Lateral cephalograms were acquired and manually reconstructed. The pharyngeal airway space is evaluated by identifying several soft and hard tissue sites and performing linear and angular measurements. The acquired data were then subjected to statistical analysis. Lower anterior face height (LAFH) and cranial base length (Na-Se-Ba) did not exhibit a statistically significant connection with PAS. MPA (mandibular plane angle) exhibited a negative connection across angular factors, but it was statistically insignificant. Other angular factors, such as the Na- Se-Ba angle (cranial base angle), SNA, and SNB, had no correlation with the posterior airway space. The conclusion of the study was that craniofacial morphology has no bearing on the pharyngeal airway space. At most, its role in pharyngeal airway irregularities is secondary and contributive.

Daraze, A et al., 2017 [159] Lateral cephalograms were obtained from 117 healthy young adult Lebanese subjects. There were 19 linear/angular cephalometric measurements of the nasopharynx, oropharynx, and hypopharynx. They measured anthropometric characteristics such as body mass index and neck circumference. There were significant variations between genders for 12 of the 19 factors examined. Males had considerably larger uvula, tongue, and distances between epiglottis-posterior pharyngeal wall and epiglottis-posterior nasal spine. Females had considerably larger anteroposterior tilt of the uvula and distances between the uvula and posterior pharyngeal wall. There were no statistically significant variations between skeleton classifications for the majority of factors. The diameters of the tongue and uvula were positively linked with BMI and neck circumference. Females may have bigger oronasopharyngeal spaces due to sexual dimorphism in relation to a number of cephalometric factors and anthropometric characteristics. In population-related comparisons, anthropometric data must be accounted for.

Swathi, K. V et al., 2019 [160] conducted a retrospective random analysis of 50 digital lateral cephalograms was done following which the cephalometric landmarks were traced. The widths of the upper and lower pharyngeal airways were measured. Additionally, the ANB angle was evaluated to categorise skeleton class patterns. There was a link between pharyngeal airway widths and skeletal class pattern. The mean upper pharyngeal airway measurements were 10.14 mm, 5.50 mm, 9.75 mm, and the mean lower pharyngeal airway widths were 4.60 mm, 7.00 mm, and 5.25 mm for skeletal class I, II, and III patterns, respectively. The average ANB angle was 1.48 degrees when correlating with skeletal class I, skeletal class II, and skeletal class III occlusions, respectively. Airway obstruction resulting in respiratory discomfort and sleep apneas is one of the most important clinical effects of pharyngeal airway

constriction. In order to increase the width of this pharyngeal space and improve the individual's quality of life as a whole, it is crucial that the individual receives the appropriate orthodontic treatment.

Ahmad L et al., 2020 [161] used modified STOPBANG questionnaire for screening of OSA-risk in adolescents and study association of OSA-risk with craniofacial and upper airway morphology. The cross-sectional study included a total of 213 participants between the ages of 10 and 19 years old, who were screened using a modified version of the STOPBANG questionnaire and then divided into two groups of 30 each, labelled "OSA risk" and "Non-OSA risk." For both groups, lateral cephalograms and cephalometric analyses were done. They found a statistically significant link between OSA risk and convex profile and class II molar relation, and concluded that teenage cephalometric and upper airway parameter alterations are associated with a high OSA risk.

Ghosh P et al., 2020 [162] did a cross sectional study to determine the prevalent risk factors of OSA and its association with craniofacial skeletal pattern in South Indian population. In the first step, 1000 individuals were categorized as snorers or non-snorers based on questionnaire responses and physical tests. In phase two, polysomnography (PSG) and lateral cephalograms were used to correlate the findings. Significantly strong correlations were observed between questionnaire-based assessments and PSG and Lateral Cephalogram findings, and the Cephalometric evaluation revealed differences in maxillomandibular relationship, airway space constriction, and inferiorly displaced hyoid bone.

Chianchitlert, A et al., 2022 [163] compared the upper pharyngeal airway dimensions of 7–14-year-old children with different skeletal types. On the basis of their skeletal patterns as indicated by the ANB angle, 361 lateral cephalometric radiographs were categorized as skeletal type I (n = 123), type II (n = 121) and type III (n = 117) radiographs. 7/8 YO (7–8 years old), 9/10 YO, 11/12 YO, and 13/14 YO radiographs were separated into four groups. SNA, SNB, ANB, Ad1-PNS, Ad2-PNS, McUP, and McLP were the cephalometric measures. ANOVA was used to compare the findings of the groups. There were significant variations between age groups for Ad1-PNS, Ad2-PNS, McUP, and McLP in skeletal types II and III. Most upper pharyngeal airway dimensions in children of skeletal types II and III were considerably larger in the 13/14-year-old age group compared to the other age groups. The upper pharyngeal airway dimensions grew proportionally with age in children aged 7 to 14 years, particularly in skeletal types II and III. In clinical circumstances, the upper pharyngeal airway dimensions could serve as a guide for identifying the various skeletal classifications.

MATERIALS AND METHOD

This study was conducted in Department of Oral Medicine and Radiology of Babu Banarasi Das College of Dental Sciences, Lucknow (UP). Ethical clearance for the dissertation was obtained from the institutional ethical committee [(IEC code – 36) BBDCODS/04/2022], in accordance with the declaration of Helsinki, for researches involving human subject.

The study population was drawn randomly from the out- patient department of Oral Medicine and Radiology. The study sample consisted of 200 patients from both genders randomly, aged between 20 to 60 years, and divided into 2 groups. Group A consists of 100 males and Group B consist of 100 females. Proper consent was taken, and was subjected to digital lateral cephalogram.

ARMAMENTARIUM (Photograph 1 and 2)

1. Dental chair with illuminating facility.

2. A pair of sterile disposable gloves and mouth mask.

3. Stainless steel kidney tray, mouth mirror, straight probe, tweezers and explorer

4. Digital lateral cephalometric machine [Planmeca Proline XC, SN:XC430638, 180-240V, 50 Hz]

SELECTION OF THE PATIENTS

Eligibility criteria were set for the patients to be included or excluded in the study.

Inclusion criteria

1. Subject well oriented to person, place and time
2. Patients who are willing and ready to participate in the study
3. Age group from 20 to 60
4. Proper visibility of soft tissue and pharyngeal airway spaces in the radiograph

Exclusion Criteria

1. Patients should not have history of any systemic disease
2. Any pathology or congenital anomaly in the palate that could affect the interpretation of the radiographic image.
3. Patient undergoing orthodontic treatment.
4. Patients below 20 years of age.
5. Patient with facial trauma.

SAMPLING METHOD

1. The study group consist of 200 individuals within the age group of 20-60 years attending the Department of Oral Medicine and Radiology, were included for digital lateral cephalometric radiographs.
2. Random sampling method has been used.

METHODOLOGY

In the present study, all the subjects fulfilling the above criteria will be enrolled after obtaining written and informed consent which was both bi-lingual in nature.

All the enrolled subjects will be divided, based on their gender. (100 male & 100 female)

STEPS PERFORMED

Steps for clinical examination

1) The subject will be selected according to the inclusion and exclusion criteria.
2) Case history will be recorded in a case history proforma, followed by STOPBANG questionnaire screening. **(Annexures 1 & 2)**
3) Each patient will be informed about the protocol and will be given appropriate instructions after obtaining a written consent. **(Annexure 3)**
4) Referred for radiographic examination.

Step For Radiographic Study

Materials and Equipment used in the study with specifications and Company

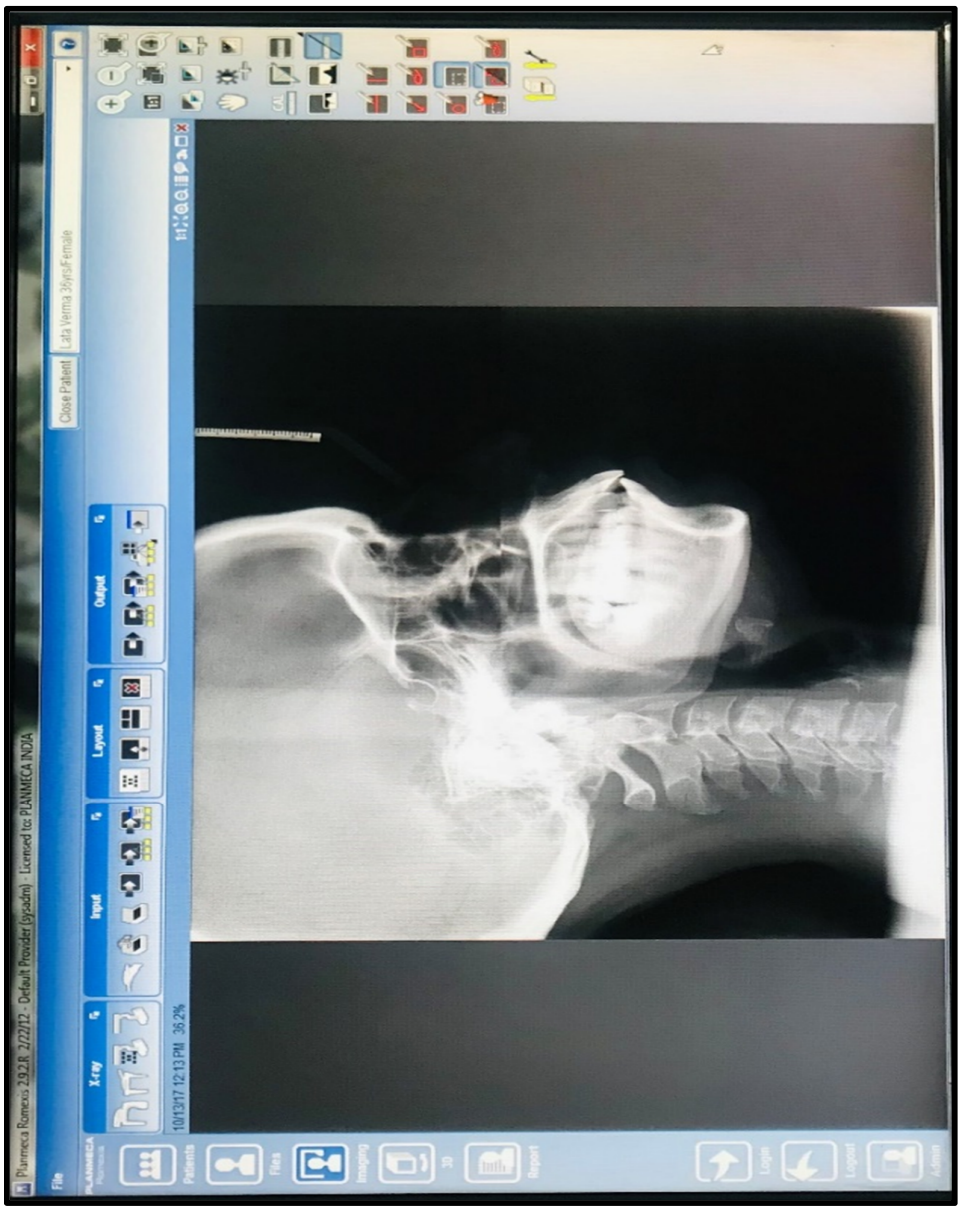
1. Digital lateral cephalometric radiograph

- [Planmeca Proline XC, SN:XC430638, 180-240V, 50 Hz]. Installed in AERB (Atomic Energy Radiation Board) certified quality assurance facility

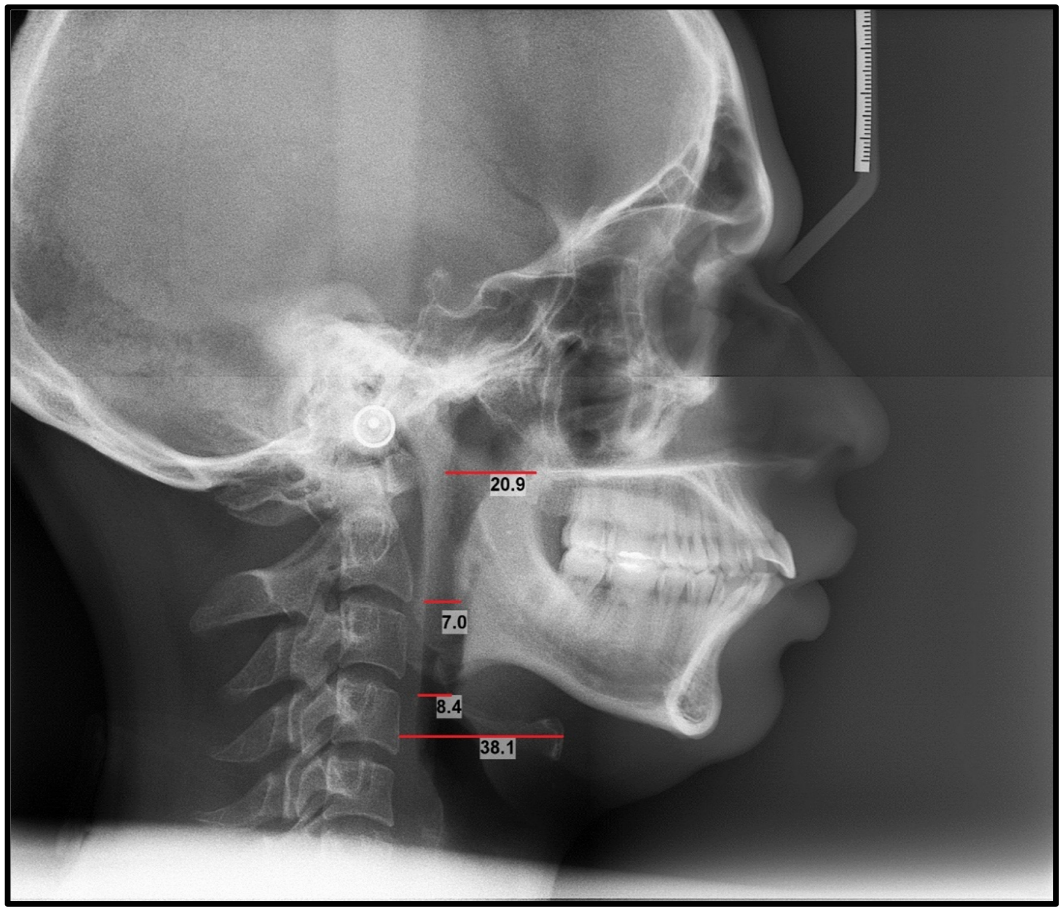
2. Planmeca Romexis 2.9.2.R software was utilized for morphometric details and data collection. **(Photograph 3)**
3. The subjects will be selected according to the inclusion and exclusion criteria as mentioned above.
4. Participants will be positioned in the cephalostat with Frankfurt horizontal plane parallel to the floor. **(Photograph 2)**
5. With upper and lower teeth in centric occlusion and oropharyngeal musculature relaxed, digital lateral cephalogram will be taken.
6. Digital radiographic measurements required for the study will be assessed with the help of Planmeca Romexis software. **(Photograph 4)**
7. **Width of Nasopharynx:** Width will be measured from the Pterygo-maxillare to the point of junction of the line perpendicular to the posterior pharyngeal wall from the posterior nasal spine.
8. **Width of Oropharynx:** Width will be measured from the tip of the uvula to the junction of the perpendicular line from tip of uvula to the posterior pharyngeal wall.
9. **Width of Hypopharynx:** Width will be measured from the Vallecula to the junction of the perpendicular line from vallecula to the posterior pharyngeal wall
10. Distance from hyoid bone to 3rd cervical vertebra will be measured.
11. All the relevant data are entered in the proforma. It is then sorted, tabulated, and statistically analyzed to draw conclusion.

PHOTOGRAPH - 1: Armamentarium – Diagnostics (kidney tray, mouth mirror, probe, explorer, tweezer), gloves, mouth mask, head cap

PHOTOGRAPH - 2: Patient along with the Lateral Cephalometric Machine



PHOTOGRAPH - 3: Romex software used for taking Lateral Cephalometric Radiograph



PHOTOGRAPH - 4: Lateral Cephalometric Radiograph with the measurement of the pharyngeal airway space and hyoid bone to 3rd cervical vertebrae.

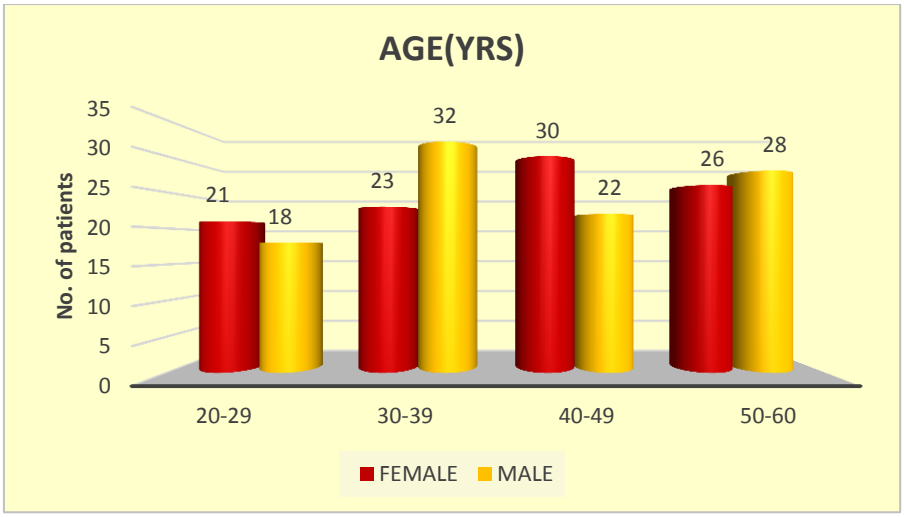
RESULTS

This Observational study was conducted at the Department of Oral Medicine and Radiology of Babu Banarasi Das College of Dental Sciences, Lucknow (UP). After obtaining ethical clearance and informed consent, 200 patients of age group 20 to 60 years were enrolled in the study according to the inclusion and exclusion criteria, after which they were subjected to lateral cephalographs. All the enrolled patients were equally divided into two groups based on their gender.

TABLE-1: Age-wise distribution of enrolled patients in both groups

AGE(YRS)	FEMALE		MALE		P-VALUE
	N	%	N	%	
20-29	21	21.00%	18	18.00%	X=3.008 **p=0.3903**
30-39	23	23.00%	32	32.00%	
40-49	30	30.00%	22	22.00%	
50-60	26	26.00%	28	28.00%	
Grand Total	**100**	**100.00%**	**100**	**100.00%**	

In the female group, 30.00% were aged between 40-49 years, followed by 50-60 years. At the same time, in the male group, 32.00% were aged between 30-39 years, followed by 50-60 years. Statistically, a non-significant difference was observed in age distribution among groups [p=0.3903]. **[TABLE - 1; GRAPH - 1]**



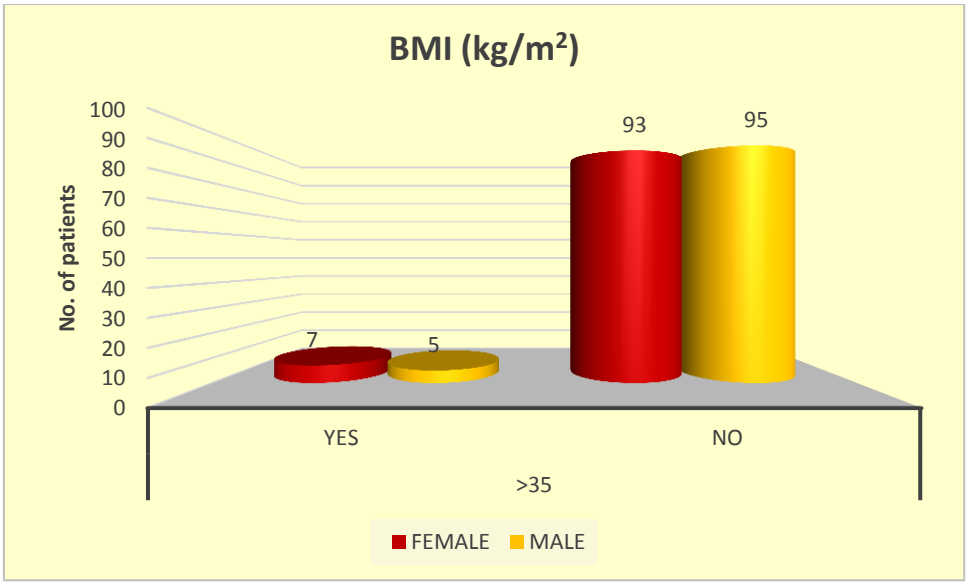
GRAPH -1: Graphical representation of the age-wise distribution of enrolled patients in both groups

TABLE- 2: Anthropometric distribution (Body Mass Index) of total enrolled patients.

BMI (kg/m^2)		**FEMALE**		**MALE**		**P-VALUE**
		N	**%**	**N**	**%**	
>35	YES	7	7.00%	5	5.00%	X=0.3546
	NO	93	93.00%	95	95.00%	**p=0.5515**

7% female patients and 5% male patients reported to have >35 BMI, followed by 93% female and 95% male patients reported to have <35 BMI. Statistically, a non-significant difference was observed in anthropometric distribution of body mass index among groups [p=0.5515].

[TABLE-2; GRAPH -2]

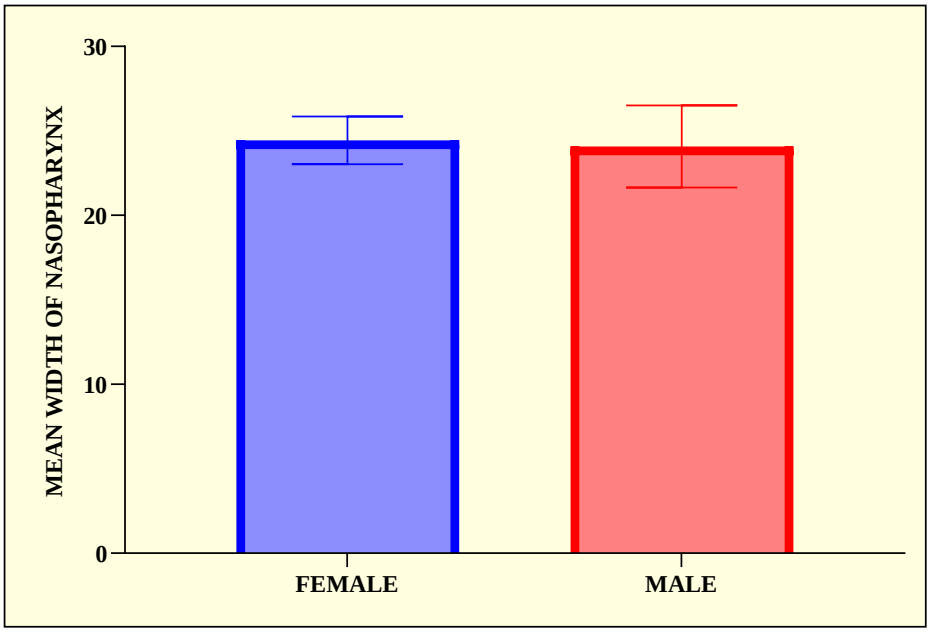


GRAPH -2: Graphical representation of the Anthropogenic distribution (Body Mass Index) of enrolled patients in both groups

TABLE - 3: Radiographic width of the nasopharynx of enrolled patients in both groups

WIDTH OF NASOPHARYNX	FEMALE		MALE		P-VALUE
	MEAN	SD	MEAN	SD	
	24.44	1.41	24.08	2.43	t=1.281 **p=0.2016**

The mean radiographic width of the nasopharynx was higher in the female group [24.44±1.41] than in the male group [24.08±2.43]. However, this difference was not significant [p=0.2016]. **[TABLE-3; GRAPH -3]**

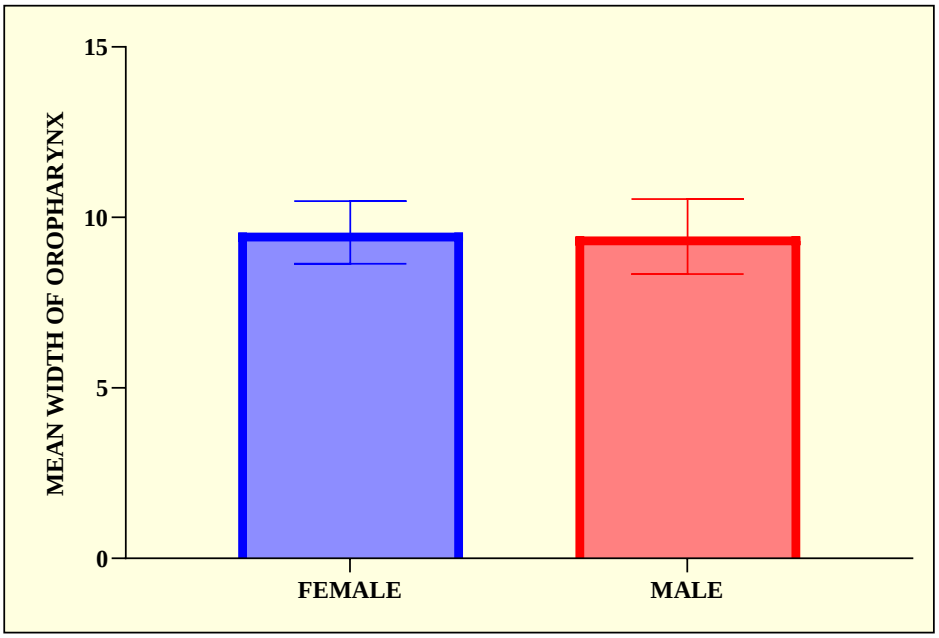


GRAPH - 3: Graphical representation of the mean radiographic width of the nasopharynx of enrolled patients in both groups

TABLE- 4: Radiographic width of the oropharynx of enrolled patients in both groups

WIDTH OF OROPHARYNX	FEMALE		MALE		P-VALUE
	MEAN	SD	MEAN	SD	
	9.56	0.92	9.44	1.10	t=0.8368 **p=0.4037**

The mean radiographic width of the oropharynx was higher in the female group [9.56±0.92] than in the male group [9.44±1.10]. However, this difference was not significant [p=0.4037]. **[TABLE-4; GRAPH - 4]**

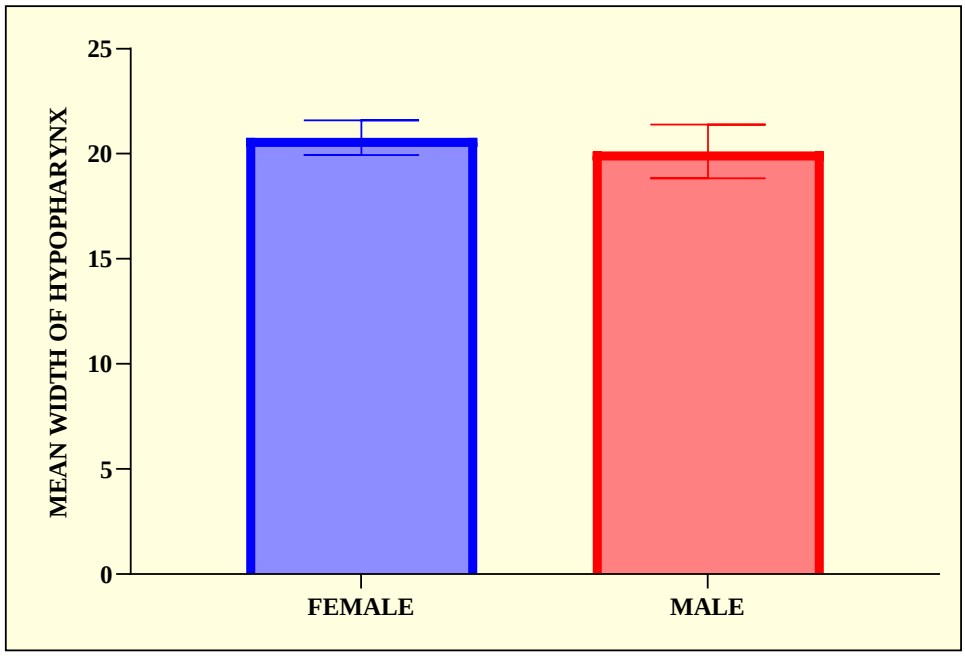


GRAPH - 4: Graphical representation of the mean radiographic width of the oropharynx of enrolled patients in both groups

TABLE -5: Radiographic width of the hypopharynx of enrolled patients in both groups

WIDTH OF HYPOPHARYNX	FEMALE		MALE		P-VALUE
	MEAN	SD	MEAN	SD	
	20.76	0.83	20.11	1.28	t=4.261 **p<0.0001***

The mean radiographic width of the hypopharynx was higher in the female group [20.76±0.83] than in the male group [20.11±1.28]. Statistically, a significant difference was noted in the mean width of the hypopharynx among groups [p<0.0001]. **[TABLE-5; GRAPH -5]**

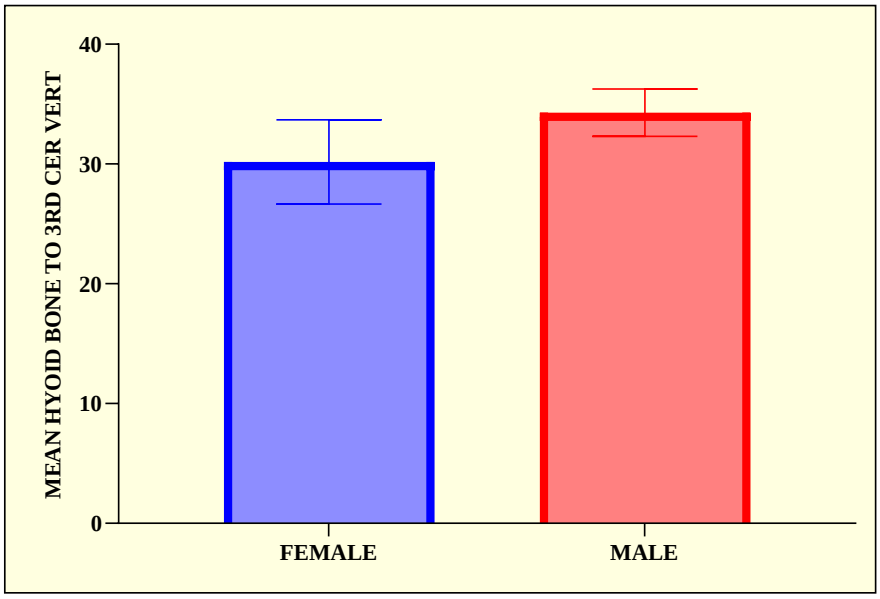


GRAPH - 5: Graphical representation of the mean radiographic width of the hypopharynx of enrolled patients in both groups

TABLE- 6: Radiographic width of Hyoid bone to 3rd cervical vertebra of enrolled patients in both group

HYOID BONE TO 3RD CER VERT	FEMALE		MALE		P-VALUE
	MEAN	SD	MEAN	SD	
	30.17	3.51	34.28	1.98	t=10.20 **p<0.0001***

The mean width of the hyoid bone to the 3rd cervical vertebra was significantly higher in the male group [34.28±1.98] compared to the female group [30.17±3.51]. **[TABLE- 6; GRAPH -6]**

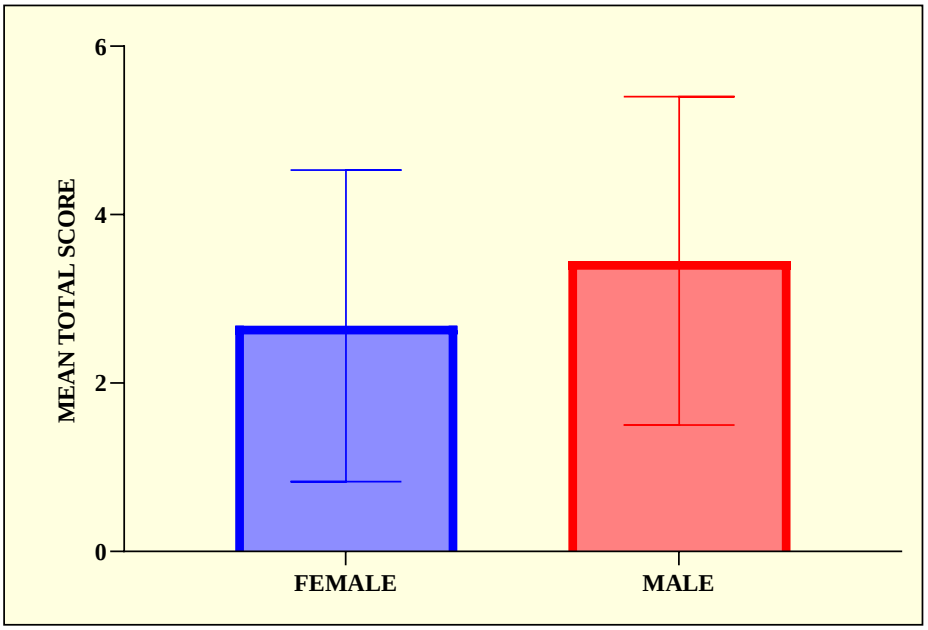


GRAPH - 6: Graphical representation of the mean radiographic width of the hyoid bone to 3rd cervical vertebra of enrolled patients in both group

TABLE- 7: Total STOPBANG Questionnaire score of enrolled patients in both group

TOTAL SCORE	FEMALE		MALE		P-VALUE
	MEAN	SD	MEAN	SD	
	2.68	1.85	3.45	1.95	t=2.865 **p=0.0046***

The mean total STOPBANG Questionnaire score was higher in the male group [3.45±1.95] than in the female group [2.68±1.85]. Statistically, a significant difference was observed in the total score of both groups [**p=0.0046***]. **[TABLE-7; GRAPH -7]**

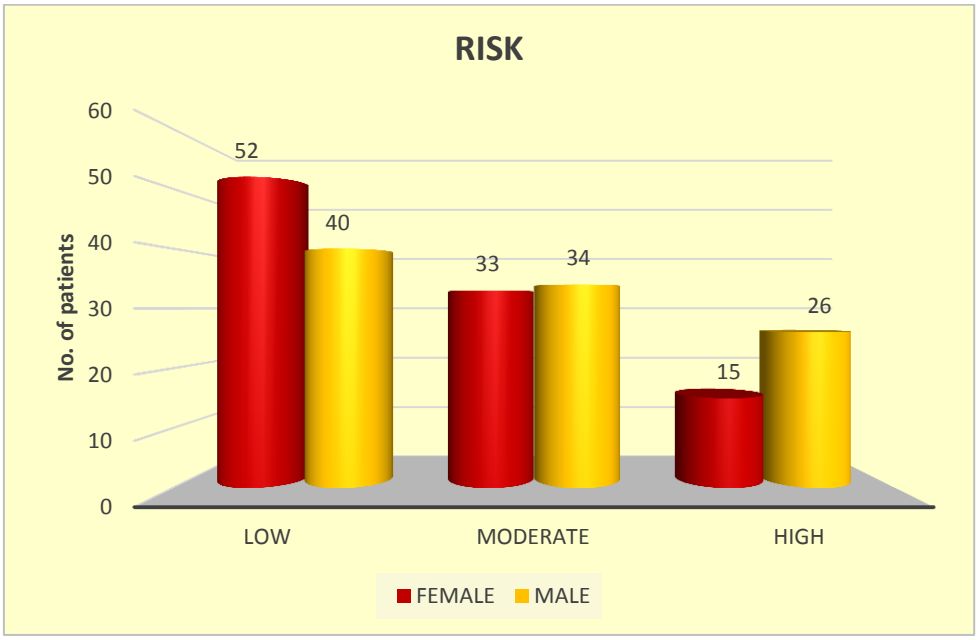


GRAPH -7: Graphical representation of the mean total STOPBANG Questionnaire score of enrolled patients in both group

TABLE- 8: Severity of risk of developing OSA (as per STOPBANG Questionnaire) in enrolled patients in both group

RISK	FEMALE		MALE		P-VALUE
	N	%	N	%	
LOW	52	52.00%	40	40.00%	X=4.531 **p=0.1038**
MODERATE	33	33.00%	34	34.00%	
HIGH	15	15.00%	26	26.00%	
Grand Total	**100**	**100.00%**	**100**	**100.00%**	

In the female group, 52.00% had a low risk of obstructive sleep apnea (OSA), while 15.00% had a high risk of OSA. In the male group, 40.00% were noted to have a low risk of OSA, while 26.00% had a high risk of OSA. However, a non-significant difference was observed in the severity of risk of developing OSA among groups [p=0.1038]. **[TABLE-8; GRAPH -8]**



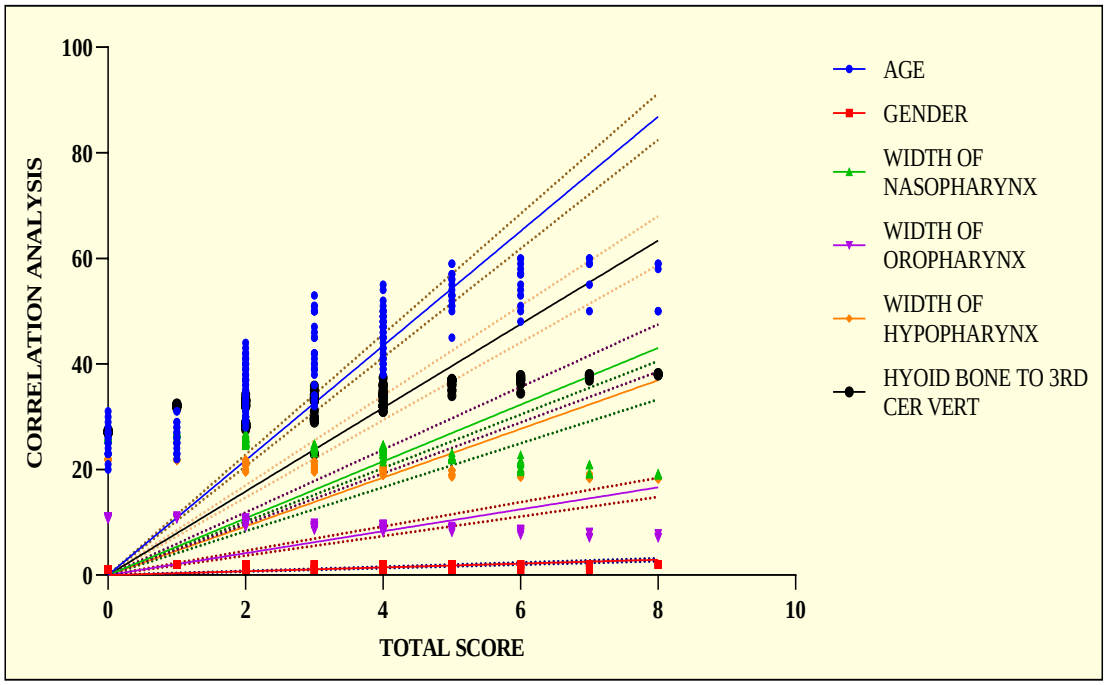
GRAPH -8: Graphical representation of the severity of risk of developing OSA (as per STOPBANG Questionnaire) in enrolled patients in both group

TABLE - 9: Correlation analysis between total STOPBANG Questionnaire score and other parameters

TOTAL SCORE VS.	Spearman r	95% confidence interval	Correlation	P value
AGE	0.9125	0.8850 to 0.9336	Very Strong (Positive)	**<0.0001***
GENDER	0.1687	0.02651 to 0.3041	Very Weak (Positive)	**0.017***
WIDTH OF NASOPHARYNX	-0.9313	-0.9480 to -0.9094	Very Strong (Negative)	**<0.0001***
WIDTH OF OROPHARYNX	-0.9197	-0.9391 to -0.8943	Very Strong (Negative)	**<0.0001***
WIDTH OF HYPOPHARYNX	-0.8946	-0.9198 to -0.8619	Very Strong (Negative)	**<0.0001***
HYOID BONE TO 3RD CER VERT	0.7985	0.7401 to 0.8450	Strong (Positive)	**<0.0001***
BMI	0.4151	0.2970 to 0.5234	Moderate (Positive)	**<0.0001***

Absolute values of r, 0-0.19, are regarded as very weak, 0.2-0.39 as weak, 0.40-0.59 as moderate, 0.6-0.79 as strong and 0.8-1 as very strong correlation.

The correlation analysis showed a significantly positive and very strong correlation between total score of STOPBANG vs age [**p<0.0001*;** r=0.9125]. Regarding gender, a significantly positive but very weak correlation was noted [**p=0.017*;** r=0.1687]. A significant, very strong, negative correlation was found between total score of STOPBANG vs radiographic width of nasopharynx, oropharynx and hypopharynx. Total score of STOPBANG vs radiographic width of hyoid bone to 3rd cervical vertebra showed a significantly positive and strong correlation [**p<0.0001*;** r=0.7985]. A Significant moderate but positive correlation was found between total score of STOPBANG vs BMI. [**p<0.0001***; r=0.4151] **[TABLE- 9; GRAPH-9]**



GRAPH -9: Graphical representation of correlation analysis between total STOPBANG Questionnaire score and other parameters

INFERENCE

In our study which was conducted in Department of Oral Medicine and Radiology of Babu Banarasi Das College of Dental Sciences, Lucknow (UP). The study population was drawn randomly which consisted of 200 patients from both genders, aged between 20 to 60 years, and divided into 2 groups, and subjected to lateral cephalograms. The following statistical inferences were drawn after analysis.

- **Age and gender distribution of the enrolled patients** [Table - 1; Graph - 1]

In the study it was found in the female group, 30.00% were aged between 40-49 years, followed by 50-60 years. At the same time, in the male group, 32.00% were aged between 30-39 years, followed by 50-60 years. Statistically, a non-significant difference was observed in age distribution among groups **[p=0.3903]**.

- **Anthropometric distribution (Body Mass Index) of total enrolled patients.** [Table-2; Graph -2]

In the study 7% female patients and 5% male patients reported to have >35 BMI, followed by 93% female and 95% male patients reported to have <35 BMI. Statistically, a non-significant difference was observed in anthropometric distribution of body mass index among groups **[p=0.5515]**.

- **Radiographic width of the nasopharynx of enrolled patients in both groups** [Table-3; Graph -3]

The mean radiographic width of the nasopharynx was higher in the female group [24.44±1.41] than in the male group [24.08±2.43]. However, this difference was not significant **[p=0.2016]**.

- **Radiographic width of the oropharynx of enrolled patients in both groups** [Table-4; Graph - 4]

The mean radiographic width of the oropharynx was higher in the female group [9.56±0.92] than in the male group [9.44±1.10]. However, this difference was not significant **[p=0.4037]**.

- **Radiographic width of the hypopharynx of enrolled patients in both groups** [Table-5; Graph -5]

The mean radiographic width of the hypopharynx was higher in the female group [20.76±0.83] than in the male group [20.11±1.28]. Statistically, a significant difference was noted in the mean width of the hypopharynx among groups **[p<0.0001]**.

- **Radiographic width of Hyoid bone to 3rd cervical vertebra of enrolled patients in both groups.** [Table- 6; Graph -6]

The mean radiographic width of the hyoid bone to the 3rd cervical vertebra was significantly higher in the male group [34.28±1.98] compared to the female group [30.17±3.51].

- **Total STOPBANG Questionnaire score of enrolled patients in both groups.** [Table-7; Graph -7]

The mean total STOPBANG Questionnaire score was higher in the male group [3.45±1.95] than in the female group [2.68±1.85]. Statistically, a significant difference was observed in the total score of both groups [**p=0.0046***].

- **Severity of risk of developing OSA (as per STOPBANG Questionnaire) in enrolled patients in both groups.** [Table-8; Graph -8]

In the female group, 52.00% had a low risk of obstructive sleep apnea (OSA), while 15.00% had a high risk of OSA. In the male group, 40.00% were noted to have a low

risk of OSA, while 26.00% had a high risk of OSA. However, a non-significant difference was observed in the severity of risk of developing OSA among groups **[p=0.1038]**.

- **Correlation analysis between total STOPBANG Questionnaire score and other parameters.** [Table- 9; Graph-9]

The correlation analysis showed a significantly positive and very strong correlation between total score of STOPBANG vs age [**p<0.0001*;** r=0.9125]. Regarding gender, a significantly positive but very weak correlation was noted [**p=0.017*;** r=0.1687]. A significant, very strong, negative correlation was found between total score of STOPBANG vs radiographic width of nasopharynx, oropharynx and hypopharynx. Total score of STOPBANG vs radiographic width of hyoid bone to 3rd cervical vertebra showed a significantly positive and strong correlation [**p<0.0001*;** r=0.7985]. A Significant moderate but positive correlation was found between total score of STOPBANG vs BMI. [**p<0.0001***; r=0.4151]

DISCUSSION

Pharynx constitutes a major part of the Upper airway and it is responsible for the function of respiration. [164] The patency of pharynx is a significant factor that influences the process of respiration and it is supported by various muscles such as genioglossus, constrictor muscles of the pharynx, muscles of the palate and hyoid bone.[165] Disparity in the muscular coordination of the pharynx may result in the collapse of the upper airway, which is considered as the hallmark of Obstructive sleep apnea.[166] There are various factors associated with development of OSA and the assessment of pharyngeal airway is considered as one of the most vital investigation in OSA cases. Though, Nocturnal polysomnography is the gold standard technique for diagnosis of OSA, various other diagnostic tools such as endoscopy and imaging modalities such as plain radiography, sonography, computed tomography, cone beam computed tomography and magnetic resonance imaging are the most commonly employed methods to assess pharyngeal air space. [166-168]

Cephalometry is a two-dimensional (2D) radiographic imaging modality that facilitates visualization of the facial skeleton and their soft tissue relationships. Lateral Cephalograms, apart from their extensive in the field of orthodontics, they are also used in screening for obstructive sleep apnea. Lateral cephalograms also aid in linear quantification of the pharyngeal air space by facilitating linear measurements. [169,170]

In the present study which was conducted in the department of oral medicine and radiology, Babu Banarasi Das College of Dental Sciences and Research, we have evaluated the morphology of pharyngeal airway space of 200 adult patients using digital lateral cephalograms, and correlated it with the obstructive sleep apnea risk score which was done by screening all the patients using STOPBANG Questionnaire.

STOP-BANG Questionnaire is a widely accepted, risk-based assessment method for determination of the risk of OSA in patients.

According to **Chung F et al. (2016)** [171] the sensitivity of STOP-Bang scoring criteria to detect moderate to severe obstructive sleep apnea and severe obstructive sleep apnea was 93% and 100% respectively. The risk of development of severe OSA is directly proportional to the increase in the score. **Nagappa et al. (2015)** [172] in their systematic review and meta-analysis have also reported greater probability of prediction of OSA using STOP-Bang criteria. Therefore, STOP-BANG Questionnaire was employed in the current study to estimate the risk of OSA among the study subjects.

1. Age and Gender distribution of the subjects (Table 1)

Our present research evaluated the morphology of pharyngeal airway space of adult patients using digital lateral cephalograms. Our study included 100 males and 100 females in the age group of 20 to 60 years. Majority of males subjects were in the age group of 30 – 39 years (N = 32), followed by 50 – 60 years (N = 28). Whereas majority of females were in the age group of 40-49 years (N = 30), followed by 50 – 60 years (N = 26). Statistically, a non-significant difference was observed in age distribution among groups [p=0.3903].

Similarly in a study by **Guttal KS et al. (2013)** [173] on evaluation of upper airway using cephalometry in 60 adults, comprised of patients within the age group of 18 years to 40 years.

Malhotra A et al. (2006) [174] did research on influence of age on pharyngeal airway space comprising of 18 men and 20 women of age range from 30 years to 60 years.

In a study by **Eikermann M et al. (2007)** [175] who analysed the impact of ageing on the pharyngeal collapsibility in 21 adult patients of various age categories, with the

help of polysomnography along with measuring the nasal pressure and epiglottic pressure. It was seen that with the increase in age there was increased incidences of upper airway collapsibility, which was independent of any gender and BMI of the patients. The increased incidences maybe accredited due to neuromuscular and anatomical changes in the upper airway with aging process. **Gonçalves RD et al. (2011)** [176] did a cephalometric analysis study of 390 patients on the effects of age and gender on upper airway, and had found that the growth of upper airway is constant till 18 years of age after which it attains the plateau.

2. Anthropometric distribution (Body Mass Index) of total enrolled patients. (Table 2)

In the present study BMI of 35 was set as the cutoff to mark obese individuals, as given in the STOPBANG Questionnaire. We found 7% females and 5% males to exhibit a BMI >35, followed by 93% female and 95% male patients reported to have <35 BMI. But no statistically significant difference was noted among the genders [p=0.5515].

According to literature evidences pharyngeal air space tends to get altered based on the amount of body fat of an individual. Obesity is considered as a major risk factor contributing to the collapse of pharyngeal airway and development of Obstructive sleep apnea because, fat deposits are reported to be more common in the sub mental and anterior laryngopharyngeal region as reported by **Horner RL et al. (1989)** [177] who did a study on the pattern of fat deposition in the pharyngeal area using MRI in 6 clinically diagnosed OSA patients. Though there are various indices measuring obesity and fat deposition, Body mass index is the most widely used index for indicating the total body fat of an individual. However, an elevated BMI is considered as a sign of obesity, and it does not represent the sort of fat in the body. There are

several studies that have established a correlation between BMI, fat distribution, and body fat percentage. But there exists a minor difference in the cut-off threshold of BMI based on the geographic locations and population, to indicate overweight or obesity. [178-180]

3. Pharyngeal airway space (radiographic width of the nasopharynx, oropharynx, hypopharynx) of enrolled patients in both groups. (Tables 3 – 5)

In the present study, width of nasopharynx, oropharynx, and hypopharynx were calculated in the lateral cephalograms of all the study subjects and were compared between males and females.

The mean radiographic width of the nasopharynx was higher in the female group [24.44±1.41] than in the male group [24.08±2.43]. However, this difference was not significant [p=0.2016]

The mean radiographic width of the oropharynx was higher in the female group [9.56±0.92] than in the male group [9.44±1.10]. However, this difference was not significant [p=0.4037]

The mean radiographic width of the hypopharynx was higher in the female group [20.76±0.83] than in the male group [20.11±1.28]. Statistically, a significant difference was noted in the mean radiographic width of the hypopharynx among the groups [p<0.0001].

Our findings can be matched with the study of **Daraze A et al. (2017)** [159] who did soft tissue element analysis in 117 young adult Lebanese patients using lateral cephalograms, and have reported significant increased nasopharyngeal width in females [24.9±3.4] than in males [23.6±3.7]. But, several other studies like that of **Grauer et al. (2009)** [122] did assessment of pharyngeal airway shape and volume of 62 patients of the age range from 17 years to 42 years using CBCT scans and

Diwakar et al. (2021) [181] who conducted a study on assessment of pharyngeal airway volume of 80 patients of mean age 15.38±1.10 years, by using CBCT data have found pharyngeal dimensions and volumes to be higher in males than in females, which is contrasting to our study.

The variations in the pharyngeal dimensions of an individual are related to several factors such as the racial and geographic differences, growth patten, age, difference in maxilla-mandibular position, pulmonary function etc. [176,181] Our finding of increase in the pharyngeal dimensions of females can be related to the sexual dimorphism and various other associated anthropometric features. It can also be attributed due to varied reproducibility of various cephalometric landmarks for the assessment of pharyngeal airway space, and different imaging protocols.

4. Radiographic width of Hyoid bone to 3rd cervical vertebra of enrolled patients in both groups. (Table – 6)

In our study the mean radiographic width of the hyoid bone to the 3rd cervical vertebra was significantly higher in the male group [34.28±1.98] compared to the female group [30.17±3.51]. [p<0.0001]

Our findings are similar to that of **Arslan et al. (2014)** [182] who did a retrospective cephalometric study of 120 patients for the assessment of hyoid bone position, and reportedly found significantly placed more superior and posterior position of hyoid in females than in males.

The distance between the hyoid bone and vertebra depends primarily on the position of the hyoid bone and mandible. Increased distance of the cervical vertebra from the hyoid bone in males can be attributed to the anterior and inferior position of the hyoid bone, which is more common in males. [183] **Trenouth and Timms (1999)** [184] did a cephalometric analysis study in 70 subjects of growing age have reported a direct

relationship between the mandibular length with the distance between the third cervical vertebra and hyoid bone. **Kolias and Krogstad (1999)** [185] did cephalometric pharyngeal analysis of 50 patients at three different ages at 10 years interval have reported change in the position of hyoid with respect to advancing age of an individual. Therefore, several factors such as position of the tongue, mandibular position and age could influence the position of hyoid bone and alter the distance between hyoid and third cervical vertebra.

5. STOPBANG Scores and Risk Assessment of the enrolled patients in both groups. (Table – 7, 8)

In the present study, the assessment of risk and severity of OSA by using STOPBANG questionnaire we found the mean total scores of males [3.45±1.95] to be significantly higher than that of females [2.68±1.85]. Our findings are consistent with several clinical studies by **Lozo et al. (2017)** [186] who executed an extensive systematic review on gender differences on sleep disordered breathing in adult population. **Malhotra et al. (2002)** [187] who did a complete study of anatomic and physiologic features of upper airway in 20 males and 20 females with the help of PSG, MRI and finite element study, and concluded that males are having higher risk of developing OSA than females. Based on the evaluation of score wise severity of OSA, we observed low risk in 40% of males and 52% of females, whereas high risk was observed in 26% of males and 15% of females. However, the difference was not statistically significant. Male gender predilection of OSA can be related to various factors such as neurochemical control mechanisms, variation in upper airway properties, arousal response, and sex hormones all of which may exert disparity in the prevalence of OSA in males and females. [188]

There have been extensive research evidences available in the literature confirming the male predilection of Obstructive sleep apnea. **Young et al. (1996)** [189] in their study observed that symptoms of OSA were more frequently reported in men than women, regardless of the disease severity. Snoring was considered as the most sensitive and greatest predictor of OSA, which is more common in men than women. Apart from this, studies indicate Apneas to be more frequently witnessed in Men than women. [190] **Vagiakis et al. (2006)** [191] who conducted a PSG study in 1010 Greek patients over a period of 3 consecutive years, reported that the duration of apnea and hypopnea are usually longer than that occur in females. Men are more prone for collapsibility of pharynx in recumbent position because of the amount of fluid displacement from the legs to the thorax and neck, which is higher than that of females. The role of testosterone in enhancing ventilatory instability resulting in loop gain of the ventilatory system is also considered as a factor behind the male predilection of OSA. [192] However, in our study we found a weak positive correlation of gender with higher scores and severity of OSA, which could be due to the smaller sample size and disparity in severity-based distribution of the study subjects.

In terms of prevalence of OSA according to high risk category as per the screening modality in our study, we found about 20.5% population amongst the enrolled patients were prone to developing OSA. The findings of our study were in line with that of **Udwadia ZF et al. (2004)** [193] who conducted a 2 phase cross sectional study in Indian urban population of age range 35 years to 65 years and reported prevalence of about 19.5%.

Interestingly it is found that prevalence rate of OSA seems to be equivalent amongst the Americans, Chinese and Indian population, which signifies OSA is not only dependant on morphological variations but having much more complex

etiopathogenesis, and a direction towards assessment of predisposing factors linked with various racial ethnicity. [194]

6. Correlation analysis between total score of STOPBANG and other parameters of the enrolled patients in both the groups. (Table – 9)

Age is also believed to be a major risk factor for OSA. In the present study, the study subjects belonged to a diverse range of age group from 20 years to 60 years. We found a strong positive correlation of increasing age with higher OSA scores [**p<0.0001*;** r=0.9125]. Our findings are consistent with that of **Fietze et al. (2019)** [195] who did PSG study on 1208 German population to find any prevalence of age and gender with the incidence of OSA. **Pinilla et al. (2021)** [196] who analyzed the role of ageing in OSA in 599 patients of suspected OSA with assessment of 5 hallmark ageing markers in blood in conjunction with AHI index. According to **Durán et al. (2001)** [197], higher prevalence of OSA has been found with healthy adults above the age of 65 years, with more than 50% of them exhibiting AHI > 5, and 20% AHI > 15 events/hour. Ageing is natural physiological process, that results various alterations in the pulmonary and muscle related mechanisms contributing to the development and progression of Obstructive sleep apnea. Airway anatomy and collapsibility of older adults is the one of the major factors which plays a causal role in obstructive sleep apnea in older adults, whereas a sensitive ventilator control system is more important in younger OSA patients [198]. **Glasser et al. (2011)** [199] had reported a two-fold increased risk of developing OSA with advancing age. Presence of associated age-related comorbidities such as hypertension, diabetes and other cardiovascular diseases are considered as predominant confounding factors related to OSA in old age. [200] However, in study, subjects with significant medical history and presence of other co-morbidities were cautiously excluded.

We also observed a very strong negative correlation among the width of nasopharynx, oropharynx and hypopharynx with the total scores, indicating that a decrease in the dimension of the pharyngeal air space to be related with Obstructive sleep apnea. There is sufficient evidence in the literature supporting our finding. **Ogawa et al. (2007)** [201] in their study found significantly reduced anteroposterior dimension of pharyngeal air space in OSA patients when compared with non-OSA individuals. **Stauffer et al. (1987)** [202] hypothesized that reduced width of the pharynx could result in defective dilation of the pharynx during inspiration resulting in apnea. **Sriram et al. (2014)** [203] confirmed that surgical intervention of the mandible and increasing the pharyngeal airway could reduce the apnea and hypopnea events, which indicates that increase in air space can aid relief from the symptoms of OSA.

In the present study, a strong positive correlation of the distance from the hyoid bone to the third cervical vertebra with OSA scores were found. Our findings are consistent with that of **Kurt et al. (2011)** [204] who did a cephalometric study of pharyngeal airway on 60 patients with having simple snoring and patients with having obstructive sleep apnea and has reported inferior position of hyoid bone. The change in the level of hyoid bone in patients with Obstructive sleep apnea might be attributed towards the change in the hypopharyngeal soft tissue which is present in chronic snorers. Since, hyoid serves as one of the major anchors of tongue muscles which restrict the upper airway anteriorly, so any anatomical changes may serve as the predisposing factor for obstructive sleep apnea.

We also observed a moderate positive correlation of Body Mass Index with OSA scores. Our findings are consistent with that of **Meyer et al. (1996)** [205] who hypothesized that increased BMI can cause change in the shape of the pharynx, resulting in reduced lateral dimension of the pharynx contributing to the development

of OSA. A linear relationship between OSA and Obesity have been reported in the literature. [206] Apart from the increased fat deposition in the pharyngeal region due to increased BMI, obesity related hormones also play a major role contributing to OSA. Leptin is a hormone involved in digestion and energy metabolism. Patients diagnosed with OSA have showed elevated levels of leptin. Increased Leptin levels are also associated with the severity of OSAS. [207] A study **Ozturk et al. (2003)** [208] demonstrated that both obesity and obstructive sleep apnea patients have elevated levels of leptin, with the level being directly related to the severity of the disease.

Our study was an attempt to evaluate the pharyngeal dimensions using lateral cephalogram and to estimate the risk of development of Obstructive sleep apnea based on evaluation of various parameter such as age, gender, BMI etc. The promising results obtained from study indicate the use of lateral cephalograms can serve as an in-expensive screening tool for assessing the linear dimensional changes of pharynx and STOPBANG Questionnaire can be used to estimate the probable risk of development and severity of Obstructive Sleep Apnea.

CONCLUSION AND SUMMARY

The present research which was conducted in the department of oral medicine and radiology, Babu Banarasi Das College of Dental Sciences and Research was aimed to evaluate the pharyngeal airway space morphology using a digital lateral cephalograms in adult patients and to estimate the risk of development of OSA using STOPBANG Questionnaire. In the study 200 patients were enrolled of equal sex distribution within age range of 20 years to 60 years

Based on the observation of the present study, following inferences were drawn,

- Maximum male patients were in the age range of 30 – 39 years, and female patients were in the age range of 40 – 49 years, along with 5% and 7% patients having high BMI ((≥35) respectively.
- The mean radiographic width of the nasopharynx was higher in the female group [24.44±1.41] than in the male group [24.08±2.43].
- The mean radiographic width of the oropharynx was higher in the female group [9.56±0.92] than in the male group [9.44±1.10].
- The mean radiographic width of the hypopharynx was significantly higher in the female group [20.76±0.83] than in the male group [20.11±1.28].
- The mean radiographic width of the hyoid bone to the 3rd cervical vertebra was significantly higher in the male group [34.28±1.98] compared to the female group [30.17±3.51].
- The mean total STOPBANG Questionnaire score was significantly higher in the male group [3.45±1.95] than in the female group [2.68±1.85], indicating male risk towards developing OSA.

- A strong positive correlation was found between the overall score and with the age of the study subjects indicating advancing age as significant risk factors for OSA.
- A very strong inverse correlation was discovered between the total score and the width of the nasopharynx, oropharynx, and hypopharynx, indicating that risk of OSA increases if the radiographic width of the pharynx decreases.
- A significantly positive and strong correlation was found between the total score and the radiographic width of the hyoid bone and third cervical vertebra, indicating the risk of OSA.

The findings of the present study are an important addition to a growing body of research that challenges the emerging standard of knowledge for this population.

However, to enhance the accuracy of the present findings and bypass the confounders, it is recommended for a further resilient, multicentric study with large sample size.

Thus, the promising results obtained from our study emphasizes the importance of lateral cephalograms and adoption STOPBANG Criteria as a screening protocol for patients susceptible to Obstructive sleep Apnea.

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ANNEXURE 1

CASE HISTORY PROFORMA

DEPARTMENT OF ORAL MEDICINE AND RADIOLOGY

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW

OPD NO. **CASE NO.** **DATE:**

NAME: **AGE:** **GENDER:**
OCCUPATION:
ADDRESS:
CONTACT NO:

CHIEF COMPLAINT:

PAST MEDICAL HISTORY:

DRUG ALLERGY:

PAST DENTAL HISTORY:

FAMILY HISTORY:

DELETERIOUS HABITS:

GENERAL PHYSICAL EXAMINATION:
BLOOD PRESSURE - BMI - NECK SIZE -

EXTRAORAL EXAMINATION:

INTRAORAL EXAMINATION:
Hard Tissue Examination:

Soft Tissue Examination:

PROVISIONAL DIAGNOSIS:

RADIOGRAPHIC INVESTIGATION: (Lateral cephalogram)

1. **WIDTH OF NASOPHARYNX –**
2. **WIDTH OF OROPHARYNX –**
3. **WIDTH OF HYPOPHARYNX –**
4. **DISTANCE OF HYOID BONE TO 3RD CERVICAL VERTEBRA -**

STUDENT'S SIGNATURE **FACULTY'S SIGNATURE**

ANNEXURE 2

STOP BANG QUESTIONNAIRE

NAME: **OPD NO:** **CASE NO:**

1. Do you Snore Loudly? **YES / NO**

2. Do you often feel Tired, Fatigued, or Sleepy during the daytime? **YES / NO**

3. Has anyone Observed you Stop Breathing or Choking/Gasping during your sleep? **YES / NO**
4. Do you have or are being treated for High Blood Pressure? **YES / NO**
5. Body Mass Index more than 35 kg/m^2? **YES / NO**

6. Age older than 50-years? **YES / NO**

7. Neck size? **YES / NO**
   male - shirt collar 17 inches/42 cm or larger?
   Female - shirt collar 16 inches/40 cm or larger?

8. Gender = Male? **YES / NO**

OVERALL SCORE – **REMARKS –**

Reference values
High Risk: 5-8
Moderate Risk: 3-4
Low Risk: 0-2

ANNEXURE 3(A)

Babu Banarasi Das College of Dental Sciences

(Babu Banarasi Das University)

BBD City, Faizabad Road, Lucknow – 227105

(INDIA)

Consent Form (English)

Title of the Study ……..
Study Number……..
Subject's Full Name…….
Date of Birth/Age ……
Address of the Subject…….
Phone no. and e-mail address……
Qualification ……
Occupation: Student / Self Employed / Service / Housewife/Other (Please tick as appropriate)
Annual income of the Subject……
Name and of the nominees(s) and his relation to the subject.....(For the purpose of compensation in case of trial related death).

1. I confirm that I have read and understood the Participant Information Document dated ……..for the above study and have had the opportunity to ask questions. **OR** I have beenexplained the nature of the study by the Investigator and had the opportunity to ask questions.
2. I understand that my participation in the study is voluntary and given with free will without any duress and that I am free to withdraw at any time, without giving any reason and without my medical care or legal rights being affected.
3. I understand that the sponsor of the project, others working on the Sponsor's behalf, the Ethics Committee and the regulatory authorities will not need my permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the trial. However, I understand that my Identity will not be revealed in any information released to third parties or published.
4. I agree not to restrict the use of any data or results that arise from this study provided sucha use is only for scientific purpose(s).
5. I permit the use of stored sample (tooth/tissue/blood) for future research. **Yes [ ] No [ ]**

Not Applicable [ ]

6. I agree to participate in the above study. I have been explained about the complications andside effects, if any, and have fully understood them. I have

also read and understood the participant/volunteer's Information document given to me.

Signature (or Thumb impression) of the Subject/Legally AcceptableRepresentative:……..

Signatory's Name……. Date …….

Signature of the Investigator…… Date……..

Study Investigator's Name..... Date……..

Signature of the witness…… Date……..

Name of the witness……

Received a signed copy of the PID and duly filled consent form Signature/thumb impression of the subject or legally Acceptable representative Date……

ANNEXURE 3(B)

Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow – 227105 (INDIA)

सहमति पत्र

अध्ययन शीर्षक.....
अध्ययन संख्या.....
प्रतिभागी के पूर्ण नाम.....
जन्म तिथि / आयु.....
प्रतिभागी का पता .....
फोन नं. और ई-मेल पता .....
योग्यता .....
व्यवसाय: छात्र / स्व कार्यरत / सेवा / ग्रहिणी .....
अन्य (उचित रुप मे टिक करें) .....
प्रतिभागी की वार्षिक आय .....
प्रत्याशीयो के नाम और प्रतिभागी से संबंध...(परीक्षण से संबंधित मौत के मामले मे मुआवजे के प्रयोजन के लिए)

1. मेरी पुष्टि है कि मैने अध्ययन हेतु सुचना पत्र दिनांक ..... को पढ व समझ लिया तथा मुझे प्रश्न पुछने या मुझे अध्ययन अन्वेषक ने सभी तथ्यों को समझा दिया है तथा मुझे प्रश्न पुछने के समान अवसर प्रदान किए गये।

2. मैंने यहॉ समझ लिया कि अध्ययन में मेरी भागीदारी पूर्णतः स्वैच्छिक है और किसी भी दबाव के बिना स्वतंत्र इच्छा के साथ दिया है किसी भी समय किसी भी कारण के बिना , मेरे इलाज या कानूनी अधिकारो को प्रभावित किए बिना , अध्ययन में भाग न लेने के लिए स्वतंत्र हुँ ।

3. मैंने यह समझ लिया है कि अध्ययन के प्रायोजक , प्रायोजक की तरफ से काम करने वाले लोग, आचार समिति और नियामक अधिकारियों को मेरे स्वास्थ्य रिकार्ड को वर्तमान अध्ययन या आगे के अध्ययन के सन्दर्भ देखने के लिए मेरी अनुमति की जरूरत नही है, चाहे मैने इस अध्ययन से नाम वापस ले लिया है। हॉलाकि मै यह समझता हुँ कि मेरी पहचान को किसी भी तीसरे पक्ष या प्रकाशित माध्यम में नही दी जायेगी।

4. मै इससे सहमत हूँ कि कोई भी डेटा या परिणाम जो इस अध्ययन से प्राप्त होता है उसका वैज्ञानिक उद्देश्य (ओं) के उपयोग के लिए मेरी तरफ से कोई प्रतिबंध नही है।
5. भविष्य के अनुसंधान के लिए भंडारित नमूना (ऊतक/रक्त) पर अध्ययन के लिए अपनी सहमति देता हुँ।

हॉ [ ] नही [ ] अनउपयुक्त [ ]

6. मै परीक्षण की अनुमति देता हुँ। मुझे इसके द्वारा यदि कोई परेशानी होती है, इसके बारे में जानकारी दे दी गई है। मैने रोगी जानकारी सूचना पत्र को पढ तथा समझ लिया है।

प्रतिभागी / कानूनी तौर पर स्वीकार्य प्रतिनिधि का हस्ताक्षर (या अंगूठे का निशान.....

हस्ताक्षरकर्ता का नाम..... दिनांक .....अन्वेषक के हस्ताक्षर ..... दिनांक .....

अध्ययन अन्वेषक का नाम .....

गवाह के हस्ताक्षर ..... दिनांक .....गवाह के नाम .....

मैनें पीआईडी और विधिवत भरे सहमति फार्म का एक हस्ताक्षर की नकल प्राप्त की.

प्रतिभागी कानूनी तौर पर प्रतिनिधि का हस्ताक्षर/ अंगूठे का निशान ..... दिनांक.....

ANNEXURE 4

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES (FACULTY OF BBD UNIVERSITY), LUCKNOW

INSTITUTIONAL RESEARCH COMMITTEE APPROVAL

The project titled **"Evaluation of Pharyngeal Airway Space Morphology using Digital Lateral Cephalogram in Adult Population."** submitted by **Dr Ribhu Ganguly** Post graduate student from the **Department of Oral Medicine & Radiology** as part of MDS Curriculum for the academic year 2020-2023 with the accompanying proforma was reviewed by the Institutional Research Committee present on **12th October 2021** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.

Prof. Vandana A Pant
Co-Chairperson

Prof. B. Rajkumar
Chairperson

ANNEXURE 5

Babu Banarasi Das University
Babu Banarasi Das College of Dental Sciences,
BBD City, Faizabad Road, Lucknow – 226028 (INDIA)

Dr. Lakshmi Bala
Professor and Head Biochemistry and
Member-Secretary, Institutional Ethics Committee

Communication of the Decision of the IXth Institutional Ethics Sub-Committee

IEC Code: 36 **BBDCODS/04/2022**

Title of the Project: Evaluation of pharyngeal airway space morphology using digital lateral cephalogram in adult population.

Principal Investigator: Dr Ribhu Ganguly **Department:** Oral Medicine & Radiology

Name and Address of the Institution: BBD College of Dental Sciences Lucknow.

Type of Submission: New, MDS Research

Dear Dr Ribhu Ganguly,

The Institutional Ethics Sub-Committee meeting comprising following four members was held on 07th April, 2022.

1.	Dr. Lakshmi Bala Member Secretary	Prof. and Head, Department of Biochemistry, BBDCODS, Lucknow
2.	Dr. Amrit Tandan Member	Prof. & Head, Department of Prosthodontics and Crown & Bridge, BBDCODS, Lucknow
3.	Dr. Rana Pratap Maurya Member	Reader, Department of Orthodontics, BBDCODS, Lucknow
4.	Dr. Akanksha Bhatt Member	Reader, Department of Conservative Dentistry & Endodontics, BBDCODS, Lucknow

The committee reviewed and discussed your submitted documents of the current MDS Project Protocol in the meeting.
The comments were communicated to PI thereafter it was revised.

Decisions: The committee approved the above protocol from ethics point of view.

Forwarded by:

Lakshmi Bala

(Dr. Lakshmi Bala)
Member-Secretary
IEC

Member-Secretary
Institutional Ethic Committee
BBD College of Dental Sciences
BBD University
Faizabad Road, Lucknow-226028

(Dr. Puneet Ahuja)
Principal
PRINCIPAL BBDCODS
Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow-226028

ANNEXURE 6
STASTICAL ANALYSIS FORMULAS

Arithmetic mean ($\bar{x}$)

Mean is one of the measures of central tendency. It finds the average value for the given data/observations. Arithmetic mean is defined as the sum of all the numbers in the data divided by the total count of numbers. The formula for finding the mean is given by,

$$\bar{x} = \frac{\sum x}{n}$$

Where ∑x is summation of all observationsn = Total number of observations

Standard Deviation (σ)

Standard deviation measures the amount of variation/dispersion of a set of values. Dispersion tells how much data is spread out. A lower standard deviation indicates that data is close to thecenter. The higher value of standard

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

deviation represents that data spread is more.

Standard Error

The standard error is one of the mathematical tools used in statistics to estimate the variability.It is abbreviated as SE. The standard error of a statistic or an estimate of a parameter is the standard deviation of its sampling distribution. We can define it as an estimate of that standard deviation.

Standard Error Formula

The accuracy of a sample that describes a population is identified through the SE formula. Thesample mean which deviates from the given population and that deviation is given as.

$$SE_x = \frac{S}{\sqrt{n}}$$

Where, *S* is the standard deviation, and n is the number of observation

P-Value

P-Value or probability value can be defined as the measure of the probability that a real-valuedtest statistic is at least as extreme as the value actually obtained.

The mentioned P in the text indicates the following:

P >0.05 – Not Significant

P <0.05 – Just significant (*)

P <0.01 – Moderately significant (**)

P <0.001 – Highly significant (***)

Spearman correlation coefficient

The Spearman correlation coefficient is defined as the Pearson correlation coefficient between

the rank variables. For a sample of size n, the n raw scores are converted to X_i *and*

$$r_s = \rho_{\mathrm{R}(X),\mathrm{R}(Y)} = \frac{\operatorname{cov}(\mathrm{R}(X), \mathrm{R}(Y))}{\sigma_{\mathrm{R}(X)} \sigma_{\mathrm{R}(Y)}},$$

Y_i areconverted to ranks R (X_i), (Y_i) and r_s is computed as

ρ denotes the usual Pearson correlation coefficient, but applied to the rank variables, cov [R(X_i),$R(Y_i)$] is the covariance of the rank variables, $\boldsymbol{\sigma}_{R(X)}$ and $_{R(Y)}$ are the standard deviations of the rank variables.

Interpretation

- The sign of the Spearman correlation indicates the direction of association between *X* (theindependent variable) and *Y* (the dependent variable).
- If *Y* tends to increase when *X* increases, the Spearman correlation coefficient is positive.
- If *Y* tends to decrease when *X* increases, the Spearman correlation coefficient is negative.
- A Spearman correlation of zero indicates that there is no tendency for *Y* to either increaseor decrease when *X* increases.
- The Spearman correlation increases in magnitude as *X* and *Y* become closer to beingperfectly monotone functions of each other.
- When *X* and *Y* are perfectly monotonically related, the Spearman correlation coefficientbecomes 1.

PLAGIARISM REPORT

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