EVALUATION OF PHARYNGEAL AIRWAY SPACE AND SOFT PALATE IN ORAL SUBMUCOUS FIBROSIS PATIENTS- A DIGITAL LATERAL CEPHALOGRAM STUDY

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LIST OF ABBRIVATIONS

Sr. No	Abbreviations	Full form
1	OSMF	Oral Submucous Fibrosis
2	OSA	Obstructive Sleep Apnea
3	OPD	Out Patient Department
4	LC	Lateral Cephalogram
5	CT	Computed Tomography
6	MRI	Magnetic Resonance Imaging
7	CBCT	Cone Beam Computed Tomography
8	SAS	Superior Airway Space
9	MAS	Middle Airway Space
10	IAS	Inferior Airway Space
11	TGL	Tongue Length
12	TGH	Tongue Height
13	LV	Length of Velum (soft palate)
14	WV	Width of Velum (soft palate)
15	PD	Pharyngeal Depth
16	NR	Need’s Ratio
17	AV	Angle of Velum (soft palate)
18	SD	Standard Deviation

Introduction

Oral Submucous Fibrosis (OSMF) is a premalignant condition affecting entire oral cavity including buccal mucosa, labial mucosa, tongue, floor of mouth, hard and soft palate and sometimes pharynx. It is chronic, progressive disorder predominantly affects people of south & south east Asia, especially Indian subcontinent where chewing of areca nut and its commercial preparation is practiced routinely. The ease of availability and wide media advertisements has led to popularity of areca nut chewing among youth and consequently, manifestations of OSMF are on the rise.[1]The prevalence of OSMF is estimated to be five million people alone in India and more recent data suggest that it has increased from 0.03 to 6.42%. [2]

The soft palate, also known as velum is posterior fibro vascular part of the palate whereas the pharynx is a wide space, lined by musculature situated behind nose, mouth and larynx. It is divided into nasopharynx, oropharynx and laryngopharynx. Both these structures participate in most of the oral functions like speech, swallowing, and respiration. OSMF causes fibrosis of lining mucosa of oral cavity, which is preceded by symptoms like burning sensation in oral cavity, ulcerations, reduced movements of tongue, blanching of oral mucosa and progressive reduction of mouth

opening.[3]There is involvement of oropharynx, nasopharynx and soft palate, causing development of nasal twang, altered speech, difficulty in deglutition and tinnitus. It also poses difficulty in intubation procedures during surgical management in them. Therefore, an evaluation of the pharyngeal airway space and soft palate in OSMF is necessary so as to get an idea of its involvement.

There is also need to evaluate soft palate and pharyngeal airway space in clinically asymptomatic people with habit.

Various studies have shown alterations in soft palate in OSMF patients, but not a single study has been documented in the literature to analyze the variations of pharyngeal airway space in OSMF patients.[4]

Lateral cephalogram has been used successfully for analysis of soft palate and the pharyngeal airway space in patients of obstructive sleep apnea and malocclusion in few studies.[5]In clinical set up lateral cephalogram is widely used, easily available, as it is less expensive, with less exposure (3-6 microSv) as compared to the recent diagnostic modalities like CT, MRI, CBCT. Thus, this two- dimensional technique may evaluate efficacy of preoperative intubation procedures by assessing upper airway in OSMF patients.

So, the present study is planned to evaluate the changes in pharyngeal area by analysis of airway space and soft palate in individuals with habits and OSMF patients.

Aim and Objectives

Aim:

To evaluate the pharyngeal airway space and morphological variations of soft palate in different stages of oral submucous fibrosis (OSMF) patients using digital lateral cephalogram.

Objectives:

Primary objectives:

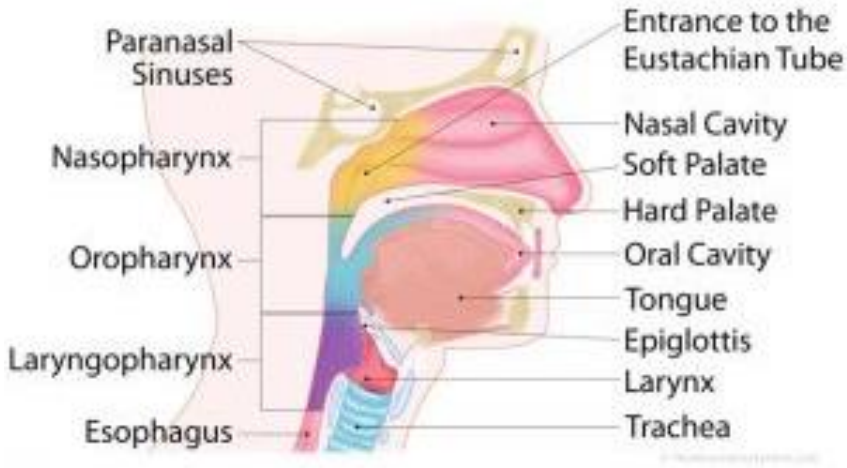
1) To assess and compare the pharyngeal airway space in healthy individuals, individuals with habit but without lesion and OSMF patients.
2) To evaluate soft palate morphological variations in healthy individuals, individuals with habit but without lesion and OSMF patients.

Secondary objectives:

1) To compare pharyngeal airway space in different stages of OSMF patients.
2) To compare morphology of soft palate in different stages of OSMF patients.
3) To assess and compare morphology of tongue in healthy individuals, individuals with habit but without lesion and OSMF patients.
4) To correlate pharyngeal airway space and soft palate in healthy individuals, individuals with habit but without lesion and OSMF patients.
5) To correlate pharyngeal airway space and soft palate in different stages of OSMF patients.

Review of Literature

An airway or respiratory tract is a respiratory organ that allows air flow during ventilation. It extends from nose, oral cavity, pharynx, larynx upto lungs. It is divided into the upper airway involving nose, pharynx and portion of larynx above vocal cord and lower airway which includes portion of larynx below vocal cords, trachea and bronchi. The cavity of pharynx consists of 3 parts: nasal part (nasopharynx), oral part (oropharynx) and laryngeal part (laryngopharynx). Upper airway is constituted by nasopharynx and oropharynx together. Nasopharynx forms upper part of pharynx, connects nasal cavity above soft palate and oropharynx extends from soft palate to upper border of epiglottis.[6]The oropharyngeal airway space is divided into superior, middle and inferior airway spaces for the ease of analysis.



Schematic representation of airway and soft palate[6]

Soft palate is the posterior fibromuscular part of the palate that is attached to the posterior edge of the hard palate. It separates the nasopharynx from the oropharynx. It participates in most oral functions, especially velopharyngeal closure which is related to the normal functions of sucking, swallowing and pronounciation. Tongue is muscular organ, situated in the floor of mouth. It is associated with functions of taste, speech, mastication and deglutition. Tongue length is measured from oropharynx to tip whereas tongue height is the highest point on most superior curvature of dorsum of tongue (Figure1).

OSMF causes alterations in the movement of tongue affecting speech and deglutition due to progressive fibrosis in soft palate and floor of mouth.[7] So, in present study the upper airway space, tongue dimensions and morphological variations of soft palate are evaluated in OSMF patients.

Various radiologic examination methods have been tried for the complete evaluation of soft palate as well as pharyngeal airway space ie oropharynx, ranging from conventional methods such as antero- posterior view, lateral cephalometry to

advanced diagnostic methods like computed tomography, magnetic resonance imaging, fluoroscopy and even cone beam computed tomography. Although advanced imaging techniques are effective methods, yet lateral cephalograms remains the most common method of analysis because of its easy availability, less radiation exposure, cost effectiveness and relatively good assessment.

OSMF is potentially malignant lesion characterized by progressive fibrosis of the submucosal tissues that affects most parts of the oral cavity, sometimes soft palate, pharynx and upper third of oesophagus.[7]It is thought that there are chances of involvement of soft palate and pharyngeal airway with the progression of disease. Some studies have reported the morphological variations in soft palate in OSMF patients, but till date no study has documented about the involvement of pharyngeal airway space.

Involvement of airway pose difficulties in intubation procedures during surgical management in OSMF. Various case reports explained the different modalities of airway management in such cases.

Eipe N (2005)[8]reviewed the airway management of 44 patients with oral malignancies and anesthetic management of 8 patients with OSMF where inter-incisor distance (IID) and Mallampati score were used to decide airway management. All patients with Mallampati score of 3 or less had successful tracheal intubation after direct laryngoscopy, whereas all those with Mallampati score 4 required fiberoptic intubation. They concluded that patients with OSMF had increased requirement for fiberoptic intubations; 62.5% (5 of 8) compared with 44.4% (16 of 36) of those with oral malignancies. They stated that OSMF contributes to the development of the

malignancy, delays the diagnoses, and complicates the anesthetic management, so various methods of airway intubation can be considered for better prognosis.

Sujee C, Ramesh C, Suresh V, Jeelani S (2011)[9] presented a case of 28 year old man diagnosed as Oral submucous fibrosis with inter-incisal distance of 1cm. Due to trismus and distortion of airway anatomy, there was difficulty in laryngoscopy and intubation of trachea. In such cases awake fibreoptic intubation under topical anaesthetia may be the ideal method to secure airway. But as it was highly discomforting to the patient, they planned surgical resection of fibrous bands bilaterally followed by temporalis muscle myotomy and coronoidectomy with appropriate reconstructive options by non invasive procedure of awake fibre optic intubation. So, airway management in such advanced cases of OSMF can be done by awake fibreoptic intubation.

Neema C (2013)[10] presented a case report about intubation in 55 year old male patient with extensive oral submucous fibrosis where intubation was an anaesthetic challenge, more so without the aid of fibreoptic bronchoscope. Patient had history of carcinoma lip, operated twice over a span of 3 years followed by cycles of radiotherapy for 2 months with mouth opening of 1/2 finger. In the absence of fibre optic bronchoscope, awake nasal intubation was done aided by capnographs and bag movements. While managing difficult airway in such cases in the absence of fibreoptic bronchoscope, alternative options can be tried and in case of emergency, tracheostomy may be necessary.

Rachana ND, Sandhya K(2014)[11] presented a case report of 32 year old male patient who was diagnosed as OSMF with interincisal distance of 1 cm. Due to restricted mouth opening and distortion of airway there was difficult intubation During procedure, fibrous bands were thoroughly released and split skin grafting was done. At the end mouth opening achieved was 2.5 cm. Airway was secured by direct laryngoscopy. So, they concluded that this method being cost effective can avoid the discomfort of awake intubation, reduce tracheostomy scarring in OSMF patients with severely restricted mouth opening.

Assessment of soft palate morphology in OSMF patients:

Mohan R, Verma S, Singh U, Agarwal N (2014)[12]evaluated the morphological variants of soft palate in oral submucous fibrosis (OSMF) patients using digital lateral cephalometry, in 100 individuals in the age range of 21-55 years. They were divided into 2 groups- disease group and control group. Six patterns of soft palate were recorded. They found type 1 soft palate in majority of OSMF patients whereas in the same group, stage III cases revealed type 3 soft palate. The length of soft palate i.e. anterio-posterior dimension was seen to be comparatively less in OSMF patients. They concluded that type 1 or type 2 soft palate was seen in initial stages of OSMF but as the disease progresses, there was an increased frequency of type 3 and 6. They also established that morphometric changes of soft palate can be taken as a useful tool to assess the severity of OSMF.

Deshmukh R, BagewadiA (2015)[13] compared morphological variations of soft palate in 60 individuals in the age range of 25-48 years with and without OSMF. They were further divided in three groups such as habit group, OSMF group and control group with 20 individuals in each group. Based on the morphology, they classified soft palate in six types where type 1 was found to be the most common type. In normal individuals and in individuals with habit, type 2 was the most common type of soft palate followed by type 1 and type3.As OSMF develops it changes from type 1 & 2 to type 6. They also found statistically significant decreased anteroposterior dimensions(32.7 mm) and increased thickness ie increased superoinferior dimensions (10.9mm) of soft palate in OSMF group as compared to other groups ($p<0.05$). They concluded that cephalometry can be efficiently used to assess the morphology of soft palate, which was altered in individuals with habit even before development of OSMF. Thickness of soft palate was affected more as compared to its length.

Khaitan T, Kabiraj A, Ginjupally U, Ramaswamy P(2015)[14] reviewed the anatomical diversification of soft palate with respect to local and systemic disorders. They have elaborated development of soft palate and its clinical and radiographic anatomy where they found that various studies have described morphological variations of soft palate. They also discussed its changes in disorders like cleft palate, obstructive sleep apnea, skeletal craniofacial malocclusion and OSMF. They concluded that knowledge about changes in soft palate in such conditions should be known to be an adjunct in clinical and radiological diagnosis and so facilitating the clinician in the adequate treatment planning and prognosis.

Tekchandani V, Thakur M, Palve D, Mohale D, Gupta R(2015)[15]evaluated the morphology of soft palate in OSMF patients using digital lateral cephalogram and

correlate it with histopathologic grade in order to propose a novel radiographic soft palate classification system for OSMF, thus eliminating need for biopsy in medically compromised patients. Total 80 persons, 40 in each group (OSMF and control) were evaluated for morphological variations of soft palate, where antero-posterior and supero-inferior dimensions were measured on cephalograms. Punch biopsy was taken from either right or left buccal mucosa for status of epithelium, degree of subepithelial fibrosis, muscle status and vasculature. They found type 1was predominant in both groups. With advancing histologic grade of OSMF, an increasing incidence of Type 6 soft palate (crooked type) was seen. They found the difference in the antero-posterior and supero-inferior dimensions between OSMF and control patients was statistically significant, indicating the severity of fibrotic changes involving soft palate. They concluded that digital lateral cephalogram can be used as non-invasive predictor of OSMF grade and especially useful for patients who are deemed medically unfit to undergo biopsy.

Raja Laxmi C, Thabusum D, Bhavana S(2016)[16] evaluated morphological patterns of soft palate in both 50 normal and 50 OSMF individuals in the age range of 20-70 years on lateral cephalograms. Six patterns of soft palate were recorded. Type 1 and 2 variants of soft palate were predominantly seen in initial stages of OSMF whereas type 3 and type 6 were observed in advanced stages. Anteroposterior (A-P) length of soft palate was significantly greater in stage I OSMF, while superoinferior (S-I) width was greater in stage III OSMF. They concluded that with the progression of staging of disease, A-P dimension of soft palate decreases and S-I dimensions increases.

Patil B, Ara B, Katti G, Ashraf S, Roohi U(2017)[17] assessed the morphological variations of soft palate with respect to different clinical stages of OSMF patients using digital lateral cephalogram. Total 300 patients were divided in two groups- study group and control group. They classified soft palate in six types based on their morphology, out of which type VI was most commonly seen in study group while type I was most common type in control group. They also concluded that as OSMF disease progressed from stage I to stage II and III, there were variations in the velar morphology from type I to type VI and type III as the degree of fibrosis increased with reduced anteroposterior and increased superoinferior dimensions of velum.

Nerkar A, Gadgil R,Bhoosreddy A, Bhadage C, Vedpathak P(2017)[18] investigated morphometric variations of soft palate on lateral cephalograms in different stages of OSMF. They also evaluated velum length, width, angle of velum and need's ratio and their correlation with respect to staging of OSMF. Total 80 subjects in the age range of 18-45 years were divided in control and OSMF group. They classified soft palate in six types out of which type 1 was found with highest incidence in both groups. Type 1 and 2 variants of soft palate were predominantly seen in initial stages while type 3 & 6 variants were observed in advanced stages of OSMF. Length and angle of inclination was found to be significantly greater in the control group while width and need's ratio was significantly greater in OSMF group. They found that as the staging increases, the length and angle of inclination decreases but width and need's ratio increases. They concluded that with the disease advancement, there was gradual increase in width, decrease in length and angle of inclination with respect to soft palate. As there was a negative correlation between angle of inclination and need’s ratio, the risk of velopharyngeal incompetence (VPI)

increases. They also stated that there are more chances of susceptibility for obstructive sleep apnea in case of advanced stage of OSMF patients.

Khoja A (2018)[19]compared the soft palate length (SPL), width and nasopharyngeal depth (PD) in total of 372 Lateral cephalograms of the patients aged 16-35 years with different sagittal and vertical skeletal patterns. They found statistically significant differences for velar width ($p = 0.008$) and Need's ratio ($p = 0.035$) amongst the three sagittal malocclusions. They also found the soft palate was largest in skeletal class I and widest in skeletal class III malocclusion. They concluded that soft palate length, width and need's ratio may vary with the underlying skeletal malocclusion.

Rathod S, Patil N, Sareen M, Meena M, Baghla P, Tyagi N(2019)[20]investigated soft palate morphology in normal individuals and different stages of OSMF patients by lateral cephalogram. Total 100 persons, 50 in each control and case in the age range of 15 to 70 were included. Type 1 (leaf shape) was the most common shape of soft palate seen in 21 cases (42.0%) of OSMF, in Grade I and Grade II whereas, type 3 (butt shape) and Type 7 (U shape) was seen in Grade III and Grade IV. They found that as the disease progresses, the long narrow type gets transformed into a short thick pattern due to fibrosis of mucosal layer over soft palate and uvula. There was a significant reduction in the length of the soft palate in case group when compared with the control group. They concluded that cephalometry can be effectively used to assess the morphology of soft palate in normal as well as a patient suffering from OSMF. Therefore, it can be beneficial in assessing fibrosis in individuals with the habit at an early stage, which can further help in prognosis.

Alok A, Singh S, Kishore M, Piyush K, Shukla A (2019)[21] evaluated morphological variations of soft palate in normal individuals and in patients with oral submucous fibrosis and obstructive sleep apnea in Darbanga (Bihar) population , 50 in each group using digital lateral cephalograms. Type 2 soft palate (rat tail shaped) was found to bein maximum subjects (18, 36%). In OSMF and obstructive sleep apnea patients, most common morphology was leaf type (type 1) (16, 32%) and (28, 56%), respectively. Overall, leaf type was the most common soft palate morphology observed followed by rat-tail shape, butt shape, crooked shape, straight shape, and S shape. They concluded that soft palate has variable morphology and it should be studied because it is an etiologic factor in various disorders like OSA. Whereas in OSMF, variations in the morphology of soft palate occurs due to fibrosis.

Various radiographic methods for evaluation of soft palate and pharynx:

Pepin J, Veale D, Ferretti G, Mayer P, Levy P (1999)[22] evaluated hooking of the soft palate in 131 awake patients with snoring with or without obstructive sleep apnea syndrome on cephalometric radiographs and computed tomographic scans. They measured posterior airway space, soft palate length and width and distance between hyoid bone and mandibular plane on cephalometric radiograph while luminal areas of the airway at the naso, oro and hypo pharyngeal levels. Among 131 patients, diagnosis of OSAS was established in 96 patients out of which 9% showed hooking of soft palate on awake cephalometric or CT images. Greater length of soft palate, wide oropharynx and wide hypopharynx was seen in patients with hooking as compared with that in patients with OSAS. Additionally patients with both OSAS and hooking

of soft palate have significantly larger posterior airway space than did other groups. They found the presence of soft palate hooking in awake patients with OSAS who had long soft palates, a wide oropharynx, and a wide hypopharynx. So, they concluded that hooked appearance of the soft palate on images of the upper airway should suspect the strong possibility of the presence of OSAS. It also confirmed 100% specificity of cephalometry and CT for the determination of soft palate and pharyngeal airway.

Johnston C and Richardson A (1999)[23] investigated morphological changes in the nasopharynx and oropharynx in 16 young healthy adults with mean age of 20.2 years had undergone cephalometric investigations and repeated the same after an interval of 32 years. They have assessed the changes in pharyngeal skeletal size, pharyngeal soft tissue thickness, pharyngeal airway depth and soft palate dimensions in addition to standard craniofacial measurements. They found increase in maxillary prominence. Measurements of anterior facial dimensions showed significant increase in upper, lower and total anterior face height. The skeletal dimensions of nasopharynx remained stable over the period between T1 and T2. There was decrease in thickness of soft tissue in the posterior nasopharyngeal wall while sagittal depth of pharyngeal lumen in the same area was found to be increased. In contrast, sagittal depth of oropharyngeal lumen was reduced. Over the period of time, there was increase in soft palate length and thickness along with increase in tongue length with age. So, they concluded that even though the bony periphery of nasopharynx remains stable during adulthood, soft tissue changes are responsible for alterations in the depth of nasopharynx and oropharynx. Lateral cephalometry can be used effectively as a tool for evaluation of changes in soft palate and pharynx.

Akcam M, Toygar T, Wada T (2002)[24] investigated the relationship between soft palate and the nasopharyngeal airway in different mandibular growth rotation models in longitudinal sample. A total of 72 lateral cephalograms were obtained from 24 individuals three years longitudinally with mean age of 10.8 years. Subjects were classified in 3 groups according to their mandibular plane angle and angle between the palatal and mandibular planes. The posterior rotation group II showed the largest increase in soft palate length (SPL) significantly whereas soft palate thickness measurement showed significant increase only in anterior rotation group III. They also noted linear increase in the superior nasopharyngeal airway space in all groups whereas inferior airway space was seen to be decreased in posterior rotation group II. Additionally the ratio between soft palate length and superior pharyngeal space demonstrated a significant increase only in group II. This ratio plays an indispensable role in velopharyngeal functions so should be preserved during the active growth period. They concluded that the soft palate dimensions and its functional relations with the surrounding structures should be examined in detail in the treatment planning of various skeletal problems in order to avoid post treatment speech problems, particularly for orthopaedic treatment involving the maxilla.

You M, Li X, Wang H, Zhang J, Wu H, Liu Y et al (2008)[25] investigated morphological variations of soft palate in 200 normal Chinese subjects on digital lateral cephalograms. According to the features of velum seen on lateral cephalogram, they classified it into six types, out of which type 1 “leaf shaped” was found to be more common in all types. There was also significant difference between pre- adult and adult group along with male and female groups in proportion to velar type. Pre-adult group presented the velar features of Type 3, while Types 2 and 4 were more common in the adult group. The velar length in type 3 was significantly shorter than

that in other types. They concluded that variable radiographic appearances of soft palate can be seen on lateral cephalometry, which can help to better understand the its morphological diversity in the median sagittal plane. These findings can be used as references for the research of velopharyngeal closure in cleft palate individuals and for aetiological research of OSAS and other conditions.

Grauer D, Cevidanes L, Styner M, Ackerman J, Proffit W(2009)[26]assessed the differences in airway shape and volume among 62 subjects with various facial patterns using cone-beam computed tomography with the iCAT software. They evaluated the pharyngeal airway shape and volume (superior and inferior compartments), done by using 3-dimensional virtual surface models to calculate airway volumes instead of estimates based on linear measurements. Anteroposterior (AP) skeletal type (Class I, Class II, or Class III) was established initially from visual inspection of the facial photographs and the lateral cephalometric radiograph. The average volume of the pharyngeal airway was 20.3 cm^3 (SD, 7.3 cm^3), with mean volumes of 8.8 cm^3 (SD, 2.9 cm^3) for the superior component and 11.5 cm^3 (SD, 4.9 cm^3) for the inferior component. They found statistically significant relationship between the volume of the inferior component of the airway and the anteroposterior jaw relationship and there was a statistically significantrelationship between sex and upper airway volume. Class III skeletal pattern had a more vertical orientation of the airway in the sagittal plane, whereas a Class II skeletal pattern was associated with a more forward orientation of the airway (P <0.001) compared with the other groups. They concluded that Airway volume and shape vary among patients with different anteroposterior jaw relationships. It can be helpful to determine the relationship of 3-dimensional pharyngeal airway surface models to facial morphology, while controlling for variability in facial size.

Parkkinen K, Lopponen H, Nieminen P, Tolonen U, Paakko E, Pirttiniemi P(2011)[27] tested the validity of two dimensional cephalometric evaluation of the pharynx with three dimensional upper airway MRI along with clinical grading of tonsillar size in 36 prepubertal Finnish children in the age range of 4.8- 9.8 years, with sleep disordered breathing. All children were imaged with low field 0.23 T open configuration MRI scanner as well as lateral cephalograms. Clinical examination of tonsils were also carried out. They found significant positive correlation of nasopharyngeal and retropalatal cephalometric measurements with MRI measurements. Whereas clinical assessment of tonsillar size correlated inversely with MRI measurements such as minimal retropalatal & retroglossal cross sectional airway area (p=0.00 & 0.015 respectively)and inter tonsillar airway width (p= 0.00). They also noted correlation of cephalometric soft palate and tonsillar area with clinical tonsillar size (p= 0.001). So, they confirmed that lateral cephalograms can be used as a valid method for measuring dimensions of nasopharyngeal and retropalatal region. Also for evaluation of oropharyngeal size, clinical assessment of tonsillar size is a relatively reliable method.

Praveen B, Amrutesh S, Pal S, Shubhasini AR, Vaseemuddin S (2011)[28] investigated various shapes of soft palate on lateral cephalograms in 80 normal individuals within the age range of 9to 31 years. They categorized soft palate into 6 types out of which type 2- rat tail shape is found to be most common in both the genders with no significant difference in proportion of various shapes of soft palate between genders. They concluded that all these types of soft palate were normal variants identifiable on lateral cephalometric radiography. Knowledge of this varied spectrum of velar morphology may help in successful functional and structural repair

in cleft palate cases, and may also be used for research about causes of OSA and related disorders.

DKumar, Gopal K(2011)[29] investigated the variations of soft palate morphology in 100 normal subjects in the age range from 15- 35 years on lateral cephalograms. They classified morphology of soft palate into six types out which type 1 leaf shaped was found to be most frequent type in 40% of the cases. They also found significant difference between male and female groups in proportion to velar type. They concluded that the morphology of the soft palate can be divided into six types according to their features on lateral cephalometry, which can help to understand better, its diversity in the median sagittal plane. These findings can be used as references for the research of velopharyngeal closure in cleft palate individuals and for the aetiological research of OSAS and other conditions.

Guttal K, Breh R, Bhat R, Burde K, Naikmasur V (2012)[30] evaluated variations of soft palate morphology along with its dimensional differences in different age and gender groups. 200 lateral cephalograms of individuals, including 79 males and 121 females in the age range of 15 to 30 years were analyzed. They categorized soft palate in six types out of which, type 1 was found to be most common showing no significant correlation between different age groups and type of soft palate. In addition to original 6 types, 2 more additional variations of soft palate were identified. A significant increase in velar length was noted with increase in age and males showed significantly increased dimensions (length and width) of velum; as compared to females. They concluded that assessment of soft palate morphology is required in sleep apnea patients and to set guidelines for orthodontic treatment planning.

Alves M, Franzotti E, Baratieri C, Nunes L, Nojima L, Ruellas A(2012)[31]evaluated the dimensions (the volume, area, minimum axial area and seven linear measurements) of the pharyngeal airway space (PAS) in 50 awake, upright children (mean age 9.16 years) with different anteroposterior skeletal patterns using cone beam computed tomography (CBCT) using Dolphin Imaging software, version 11.0. The patients were divided in two groups according to the ANB angle. Group I comprised 25 patients (14 boys, 11 girls) with ANB angles ranging from 28 to 58 whereas Group II had 25 (13 boys, 12 girls) who had ANB angles greater than 58. Statistically significant differences was seen with ANB, SNB, PAS-UP, airway volume, airway area and minimum axial area. They found that patients with mandibular growth deficiency had less airway volume, airway area, minimum axial area and PAS than the patients with good growth anteroposterior relationship between maxilla and mandible. As PAS and the skeletal pattern have a close relationship so they concluded that the evaluation of PAS should be part of diagnosis and treatment planning because the detection and correction of airway abnormalities during development can influence normal dentofacial growth.

Guttal K, Burde K (2013)[32] evaluated measurements of upper airway space in healthy young North Indian subjects including 30 males and 30 females in the age range of 18-40 years through lateral cephalometric analysis. Total 60 lateral cephalograms were evaluated for linear and angular measurements. Among all linear variables, length of tongue, tongue height, soft palate thickness, depth of hypopharynx, region of minimal airway space, inclination of soft palate, vertical and horizontal distances of vallecula and position of hyoid in vertical and horizontal plane were found to be larger in males as compared to females. Similarly among the areas assessed, tongue area, oral area, nasopharyngeal area were significantly higher in

males. They concluded that hypo pharyngeal and oropharyngeal spaces were larger in males. They also concluded that cephalometry has proved to be a useful adjunct not only for orthodontic treatment planning but also for assessment of upper airway related structures.

Verma P, Verma K, Kumaraswam C, Basavaraju S, Sachdeva S, Juneja S (2014)[33] investigated variations of soft palate morphology in different age and gender groups in association with velar length, velar width, pharyngeal depth and Need's ratio in the North Indian subpopulation in 300 subjects aged between 15 and 45 years. Type 1i.e. leaf shaped was found to be the most frequent and crook shaped was the least common among both the genders and various age groups whereas mean velar length, velar width and pharyngeal depth were significantly higher in males and the Need's ratio was seen to be larger among females. A consistent increase in velar length was also noted with increase in age. They concluded that cephalometric analysis is the most commonly used technique for evaluating velar and pharyngeal morphology, which plays an important anatomic role in functional rehabilitation of speech, breathing, and hearing. It also helps in a better understanding of management of patients of the velopharyngeal closure and craniofacial anomalies like cleft lip/palate, enlarged adenoids, obstructive sleep apnea, poorly retained maxillary denture.

Gupta S, Subrahmanya R (2014)[34] compared and correlated the upper and lower oropharyngeal widths in 60 individuals with equal no of males and female in the age range of 16-20 years with different skeletal patterns on vertical plane. Accordingly they were divided in horizontal and vertical growth pattern and linear measurements of pharyngeal width were done on lateral cephalograms based on McNamara analysis.

A significant correlation was found between the facial skeletal pattern and upper and lower oropharyngeal width. They found narrower upper oropharyngeal width and wider lower oropharyngeal width in subjects with vertical skeletal pattern. They concluded Variations in upper and lower oropharyngeal widths and posture of the tongue in horizontal and vertical skeletal pattern. It also proves the existence of a relationship between facial skeletal patterns and upper and lower oropharyngeal widths.

Diwakar R, Sindhu M, Prabhakar M, Grover S, Phogat R (2015)[35]evaluated the pharyngeal airway volume in 40 North Indian subjects with the age range from 14 to 25 years with different vertical growth patterns using cone beam computed tomography. Horizontal growers and vertical grower consisted of 13 subjects whereas normal growers consisted of 14 subjects. CBCT scans were acquired with i-CAT Cone Beam 3D Dental Imaging system. In the present study, the pharyngeal airway was measured three dimensionally as a volume, calculated with the help of *In Vivo* 5.1 Anatomage Software. Total pharyngeal airway volume was found to be 17.84 cm^3 for normal growers, 17.35 cm^3 for horizontal growers and 17.43 cm^3 for vertical growers. In comparison of normal and horizontal growers. The volume of nasopharyngeal airway was found to be more in Group 2 (normal growers), and oropharyngeal airway volume was found to be more in Group 1 (horizontal growers). Similarly in comparison of normal with vertical growers, nasopharyngeal airway volume was found to be more in Group 2, and oropharyngeal airway volume was found to be more in group 3 (vertical growers). The volume of nasopharyngeal airway was not found to be significantly different when compared between the horizontal growers and the controls and between the vertical growers and the controls. So, they concluded that

the volume did not differ with difference in the vertical growth trend and it was possible to evaluate the pharyngeal airway volume three dimensionally.

Samdani D, Saigal A, Garg E (2015)[36] investigated correlation between various shapes of soft palate and types of malocclusion in 250 healthy North Indian individuals in age groups of 14-28 years. All the subjects were categorized according to Angle's classification of malocclusion and various shapes of soft palate were evaluated on lateral cephalograms. Angles's class II malocclusion was found to be most common among both genders followed by class I and class III. Out of six types, rat tail typeof soft palate was most frequently found in both the genders. Comparison between type of malocclusion and shapes of soft palate revealed association of rat tail type (type2) with class I malocclusion, leaf shaped type (type1) with class II malocclusion and crooked shaped (type6) soft palate with class III malocclusion. They concluded that there was a significant correlation between variants of soft palate and types of malocclusion. Similarly, the knowledge of morphological variants of the soft palate helps to get a better understanding of the velopharyngeal closure and also in successful functional and structural repair in cases of cleft palate and in the etiological study of OSAS, snoring and other conditions.

Smriti K, Pai K, Vineetha R, Pentapati K(2015)[37] investigated variations of soft palate morphology and its proportional differences between males and females in 100 normal healthy individuals comprising 50 males and 50 females in the age range of 15 to 45 years on digital lateral cephalograms. Type 1 leaf shaped soft palate was found to be the most commonest shape, followed by type 6, types 2, 3 & 4 and least being type 5. Additionally, no significant difference was seen in the distribution of shape of soft palate between males and females. They concluded that lateral cephalogram can

help to better understand the diversity of the velar morphology and can be used as references for the research of velopharyngeal closure in cleft palate individuals, obstructive sleep apnea syndrome (OSAS) and other conditions.

More C, Saha H, Vijayvargiya R(2015)[38] evaluated morphology and variations of soft palate through computed tomography in different age groups and gender. Total 300 voluntary healthy participants with equal number of males and females aged 18-80 years were subjected to CT scan of head and neck region (sagittal view) and shapes of soft palate were classified into six types. Out of these six types, type 3 ie butt type was the commonest. Whereas, correlation of shape of soft palate with age group and gender were statistically was found to be non significant. Mean values for antero-posterior and supero-inferior length of various shapes of soft palate in both the genders were highly significant. The mean A-P length of soft palate in males was seen to be more than females, which was statistically significant. While, the mean S-I length of soft palate in males was less than females, being non significant statistically. They concluded that CT scan is an important diagnostic aid for studying the accurate morphology of soft palate. It can help as a reference for research pertaining to cleft palate/ velo-pharyngeal closure and in obstructive sleep apnoea syndrome.

Mani P, Muthukumar K, Krishnan P, Kumar K (2015)[39] compared the widths of the upper and lower pharyngeal airway space in skeletal class II malocclusion with low, average and high vertical growth patterns in the individuals age ranging between 14 to 25 years in West-Tamil Nadu population. Lateral cephalograms of 90 patients were evaluated and divided them in 3 groups depending on vertical facial patterns as Normodivergent, Hypodivergent & Hyperdivergent including 30 patients each and McNamara analysis was performed to measure pharyngeal airway space. They found

statistically significant narrow upper pharyngeal airway width in the hyperdivergent facial pattern subjects as compared to normodivergent and hypodivergent facial patterns whereas no significant difference was seen in all three vertical patterns in lower pharyngeal airway space. They concluded that narrow pharyngeal airway space is one of the predisposing factors for mouth breathing and obstructive sleep apnea. So, orthodontists should recognize these pharyngeal airway morphologies during the time of diagnosing and treating the preadolescent children to prevent undesirable craniofacial development.

Bronoosh P, Khojastepour L(2015)[40] assessed the correlation between the area and the volume measurements of pharyngeal airway size in a lateral cephalogram and a 3 dimensional CBCT scan in 35 adolescent subjects with mean age of 21.74+ 2.63 years. 2D measurements of airway area was done from lateral cephalograms where airway volume over the same region was done from 3 D CBCT. They found strong correlation between pharyngeal airway area on lateral cephalogram and its true volumetric size from CBCT images. They also found both area and volume of pharyngeal airway were found to be significantly greater in male patients. Pharyngeal airway area on a lateral cephalogram is correlated strongly with volumetric data on CBCT images. So they concluded that the use of CBCT images for volume measurements and lateral cephalograms for area measurements in orthodontic patients can aid in the better evaluation of airways and acted as a diagnostic instrument in this area.

Ansar J, Singh R, Bhattacharya P, Agarwal D, Verma S, Maheshwari S(2015)[41] compared the pharyngeal airway dimensions by cephalometric examination of 90 individuals aged between 16-25 years with different morphological patterns. According to vertical growth pattern of mandible, they were divided in 3 groups ie. hypodivergent, normodivergent and hyperdivergent. The upper and lower pharyngeal airway widths were measured using McNamara analysis. They found statistically significant narrow upper airway width in hyperdivergent growth pattern (P< 0.001). They also found most significant difference between lower airway width of hyperdivergent and hypodivergent group (P= 0.011). The hyperdivergent patients had statistically significant narrower upper and lower pharyngeal width as compared to normodivergent and hypodivergent growth pattern. These patients may be more prone to mouth breathing as a result of their relatively diminished pharyngeal dimensions. So, they concluded examination of pharyngeal dimension is important so as to reduce the chances of mouth breathing and it can be very well assessed by cephalometric radiographs.

Kaur S, Rai S, Sinha A, Ranjan V, Mishra D, Panjwani S (2015)[5] evaluated the relationship of craniofacial structures and pharyngeal airway space along with soft palate and tongue on a lateral cephalogram along with body mass index (BMI)and neck circumference (NC) for evaluation of predictors of sleep apnea in 45 patients in the age range of 18-25 years. Based on the sagittal skeleton pattern, all the patients were divided into three groups. Various linear and angular measurements of upper airway and soft tissue area were done on lateral cephalograms. Significant difference was found between class I, II and III groups at the nasopharynx and oropharynx levels. It was found that with increase in ANB angle ie in class II, there was overall lesser dimensions of upper airway area. They concluded that sagittal skeleton pattern

had close association with dimensions of pharyngeal airway passage. Additionally they found that BMI increased progressively with increasing NC. Patients with increasing NC with large dimensions of upper airway soft tissue (increased soft palate and tongue size) suggested that obesity mediates its effects in OSA through fat deposition in the neck. It could provide predictive information about the severity of OSA and insights into the possible underlying cause of OSA.

Nagaraj T, Goswami R, James L, Sreelakshmi N, Veerabasavaiah B, R. Shruthi et al (2016)[42] assessed and classified the variations in the size and shape of soft palate. They investigated the differences in the size and shape of velar morphology in lateral cephalograms of 200 individuals of age groups of 8-35 years. Along with eight basic types, they found three new types of soft palate viz cone shaped, triangular shaped and v shaped. Type 1 soft palate was more prevalent followed by types 2 and 3. Furthermore, velar length and width was found to be greater in males than females. They also found significant increase in velar length till age of 30 years, following which there was decrease. They concluded that it will be beneficial for diagnosis and management of OSA and also in assessing the changes in the morphologies in OSMF and cleft palate patients.

Tarkar J, Parashar S, Gupta G, Bhardwaj P,Maurya R, Singh A et al (2016)[43] evaluated the upper and lower pharyngeal airway dimensions, posture of tongue and hyoid bone position in 90 young adults within age range of 18-32 years with different growth patterns on lateral cephalograms. Subjects were divided in three groups of 30 each depending on different growth pattern of face ie group 1 with average growth pattern, group 2 with horizontal growth pattern and group 3 with vertical growth. The upper oropharyngeal width was found to be highly significantly different (p=0.0) in

different skeletal patterns. Vertical skeletal pattern was significantly narrower upper airways than those with horizontal skeletal pattern (p= 0.025) Similarly, significantly higher difference was found in position of dorsum of tongue in vertical growth pattern group (p= 0.0). They also found that the hyoid bone was positioned more inferiorly and posteriorly in horizontal growth pattern (brachyfacial) as compared with dolichofacial and normal subjects (p=0.044). They concluded that variations were seen in upper and lower oropharyngeal widths, posture of the tongue and hyoid bone position in all the growth patterns. So, these parameters can be used as clinical guidance to assess airways abnormalities in long term and predict prognosis and treatment modalities.

Eslami E, Katz E, Baghdady M, Abramovitch K, Masoud M (2016)[44] had systematically reviewed the literature correlating upper airway measurements from lateral cephalograms (LC) and CBCT/CT scans to determine the utility of using LC to predict three dimensional airway parameters. Total 11 studies were evaluated from a comprehensive electronic search which includes CT scans, CBCT scans involving nasopharyngeal, oropharyngeal, velopharynx and hypo pharyngeal spaces. 4 studies had investigated the correlation between CT supine and LC, where 7 studies evaluated correlation between LC and CBCT scans. It showed weak to strong correlation in nasopharyngeal segment, strong correlation in oropharyngeal segment and weak correlation in hypo pharyngeal segment. They found higher correlations for upright CBCT and upright LC than LC in an upright position and CT scans in supine position. The adenoid nasopharyngeal ratio and linear measurements from Posterior Nasal Spine (PNS) to posterior pharyngeal wall on conventional LC can be used as initial screening measurements to respectively estimate volume and area of the nasopharyngeal upright measurements from CBCT. Similarly the oropharyngeal area

measurements from LC can also be used to predict upright upper airway 3D volume as an initial screening measurements.

Zimmerman J, Lee J, Pliska B(2016)[45]systematically reviewed the literature to evaluate the reliability of upper pharyngeal airway assessment using dental CBCT. The electronic databases of MEDLINE, EMBASE, and Web of Science were searched through June 2015. The selected studies included the CBCT scans of 956 patients evaluated for reliability of upper pharyngeal airway assessment. The 42 studies exhibited considerable variations in sample size (ranging from 4 to 71 scans), mean patient ages (ranging from 8 to 48 years), imaging software, machine settings, and examiner protocols. The most commonly used CBCT machine was i-CAT (Imaging Sciences International), and the most frequently used imaging software was Dolphin Imaging®. From the high-quality studies, upper airway volume showed good-to-excellent intra-examiner reliability (0.880–0.990) and minimum cross-sectional area showed moderate–to-excellent intra-examiner reliability (0.780–0.999). Upper airway volume demonstrated excellent interexaminer reliability (0.986–0.998), whereas minimum cross-sectional area demonstrated moderate-to-excellent inter-examiner reliability (0.696–0.988). Based on the current and limited evidence, they concluded that upper pharyngeal airway assessment with CBCT demonstrated moderate-to-excellent intra- and inter-examiner reliability for volume and minimum cross-sectional area.

Sprenger R, Martins L, Santos J, Menezes C, Venezian G, Degan V(2017)[46] evaluated the nasopharyngeal, oropharyngeal and hypo pharyngeal airway spaces variations in brachyfacial, mesofacial and dolichofacial in Angle class I individuals. 45 digital lateral head teleradiographs of adult individuals were analyzed and divided

into 3 groups as per the craniofacial growth pattern. Sleep apnea cephalometric measurements were used to evaluate the airways and found that the median posterior palatal measurement in the oropharyngeal region was lower for individuals with dolichofacial pattern in comparison to mesofacial and brachyfacial patterns and statistically significant difference was verified among the groups (p= 0.020). They concluded that there were no differences in nasopharyngeal and hypopharyngeal airway spaces in brachyfacial and mesofacial individuals in the median posterior palatal measurement.

Alok Kumar, Nandi M (2017)[47] evaluated the effect of craniofacial morphology on pharyngeal airway space in 30 adult female patients with skeletal class I jaw relation. Linear and angular measurements were carried out on lateral cephalograms to evaluate the pharyngeal airway space. The linear variable like lower anterior face height and cranial base length did not show statistically significant correlation with pharyngeal airway space. Similarly mandibular plane angle showed mild negative correlation with airway space which was statistically non significant. The cranial base angle, SNA and SNB did not correlate with posterior airway space. They concluded that craniofacial morphology was one of the important factors affecting pharyngeal airway space.However, craniofacial morphology did not have any significant bearing on the pharyngeal airway space.

Barrera J, Pau C, Forest V, Holbrook A, Holbrook G(2017)[48]determined correlation of anatomic dimensions with obstruction in adult sleep apnea (OSA) compared to control subjects and compared airway dimensions ascertained from 2D (lateral cephalometry) and 3DImaging (MRI) in total 28 patients. Lateral cephalometry was performed in 10 patients and skeletal structures were measured.

From MRI scans, maximum thickness of the soft palate, maximum length of the soft palate, Posterior Airway Space (PAS) diameters at the nasal, occlusal and mandibular plane, PAS cross-sectional area and tongue volume were measured. Using both imaging modalities, the soft palate length did not differ between the OSA and non-OSA patients compared to controls, the mandibular plane-hyoid (MP-H) distance was significantlylonger in the OSA group as measured with either type of imaging. Mandibular PAS diameter, when measured by radiocephalometry was significantly shorter in the OSA group as, was not found to differ significantly between control and OSA subjects when assessed by MRI. Both imaging modalities showed that the PAS cross-sectional areawas smaller in the OSA group compared to controls (P = 0.002). The nasal and occlusal PAS diameters were measurable only with 3-D MRI, demonstrated a significantly shorter nasal PAS diameter in the OSA group (P= 0.02). They found that cephalometry and MRI produced similar results for measures of soft palate length and MP-H distance. They concluded that anatomic parameters including a small PAS diameter at the nasal plane, a smaller PAS area, a long MP-H distance, and a large tongue volume hold statistical and clinical relevance in patients with OSA. So, tomographic MRI is an accurate and informative imaging study for the assessment of anatomic airway measures which possibly guide surgical planning.

Daraze A, Delatte M, Liistro G, Majzoub Z(2017)[49] assessed the dimensions of soft tissue elements of the upper pharyngeal space in 120 healthy young adult Lebanese subjects in the age range of 21-25 years and evaluated its potential correlations with modifying variables such as gender, skeletal class and anthropometric parameters. Digital lateral cephalograms were taken and subjects were classified into 3 skeletal sagittal types according to their ANB angles as class I, II and III. Anthropometric measurements such as body mass index and neck circumference were also recorded.

Uvula and tongue dimensions and the distance between epiglottis- posterior pharyngeal wall and epiglottis- posterior nasal spine were significantly larger in males whereas the anteroposterior inclination of the uvula and distances between the uvula and posterior pharyngeal wall were significantly greater in females. The significant differences were demonstrated between classes II and III relative to the uvula area and uvula thickness with class III individuals showing greater values than class II subjects. Similarly, all anthropometric measurements of body mass index and neck circumference were significantly greater in males than females. They also found significant positive correlation between the vertical airway length of the pharynx and both BMI and neck circumference. They concluded that sexual dimorphism relative to some cephalometric variables and anthropometric parameters may account partly for larger oronasopharyngeal spaces in females. Such correlations are extremely important to account for in ethnic- and population-related comparisons of UAS dimensions as they can be incriminated in the differences demonstrated between ethnic groups.

Khare P, Reddy G, Gupta A, Shaiva V, Handa H (2019)[4]reviewed the use and efficacy of lateral cephalogram (LC) and CBCT in measuring airway in OSMF patients. OSMF may have limited mouth opening and as such may pose challenges in intubation. The 2-Dimensional technique of lateral cephalogram may evaluate efficacy of preoperative intubation procedures as well as give an idea about the reduced area of upper airway in OSMF patients with poor prognosis. OSMF changes may lead to alterations in nasopharynx, oropharynx volume which can be assessed by Cone Beam ComputedTomography (CBCT) accurately as compared to LC. So, they concluded while moving towards the era of imaging, CBCT may become a more

acceptable diagnostic technique surpassing the other 2-dimensional techniques like LC.

Materials and Methods

This is a hospital based cross sectional, observational prospective study which was initiated after approval from Institutional ethics committee and was carried out in the Department of Oral Medicine and Radiology along with Department of Orthodontics and Dentofacial Orthopaedics. Informed consents were obtained from each patient.

Total 240 subjects of age above 18 years were selected from the outpatient department of Oral Medicine and Radiology. They were included as per inclusion and exclusion criteria in the study and were divided in 3 groups.

Group A - 40 Healthy individuals with no habit & no lesion

Group B - 40 individuals with habit but no lesion

Group C - OSMF Patients

- C1(Group 1)- 40
- C2 (Group 2)- 40
- C3 (Group 3)- 40
- C4 (Group 4)- 40

Inclusion criteria

- Clinically diagnosed patients of OSMF. (as per Khanna and Andrade classification)[7]
- Individuals willing to participate in the study.
- Individuals with habit of arecanut chewing atleast since 1 year.
- Individuals with Angle's class I malocclusion

Exclusion criteria

- Patients under treatment or previously treated for OSMF.
- Patients with systemic diseases like Obstructive Sleep Apnea and any acute infections or allergies involving upper pharyngeal airway.
- Patients with any neck deformity.
- Patients with any defect/ pathology of palate or any previous history of cleft palate surgery.
- Pregnant patients.

Materials:

I) Armamentarium for clinical examination:

- Mouth mirror
- Straight probe
- Kidney tray
- Sterile gloves
- Face mask
- Digital vernier caliper

II) Digital lateral cephalograms using CS 8100 SC Carestream Digital Panoramic and Cephalometric System

Methodology:

Clinical examination

1. After obtaining informed consent from all the subjects, detailed clinical history was recorded and clinical examination was carried out in dental chair under proper illumination.

2. Patients with OSMF were graded clinically as per classification given by Khanna and Andrade.

3. All the subjects were divided into three groups as per criteria.

Digital Lateral cephalogram:

1. Digital lateral cephalograms were taken using CS 8100 SC Carestream Digital Panoramic and Cephalometric System with a tube voltage of 80-90 kV, tube current of 8-12 mA, and exposure time of 10s with all protective measures.

2. After clinical examination, participants were positioned in cephalostat with Frankfort plane parallel to the floor and were asked to swallow once to clear any saliva in the oral cavity and pharynx and then to close their mouth tightly to place their teeth in centric occlusion and with their oropharyngeal musculature relaxed and were subjected for digital lateral cephalogram.

Evaluation of Digital Lateral Cephalograms:

The pharyngeal airway space, soft palate and tongue were evaluated on lateral cephalograms using McNamara's analysis (Nemoceph Software, version 6.0 Nemotec SRL, Spain).

The linear measurements and angles were recorded in mm and degrees respectively along with evaluation of soft tissue such tongue.

Pharyngeal Airway Space measurements:

- Superior airway space (SAS):- It is measured from a point on the posterior outline of the soft palate to the closest point on the pharyngeal wall.

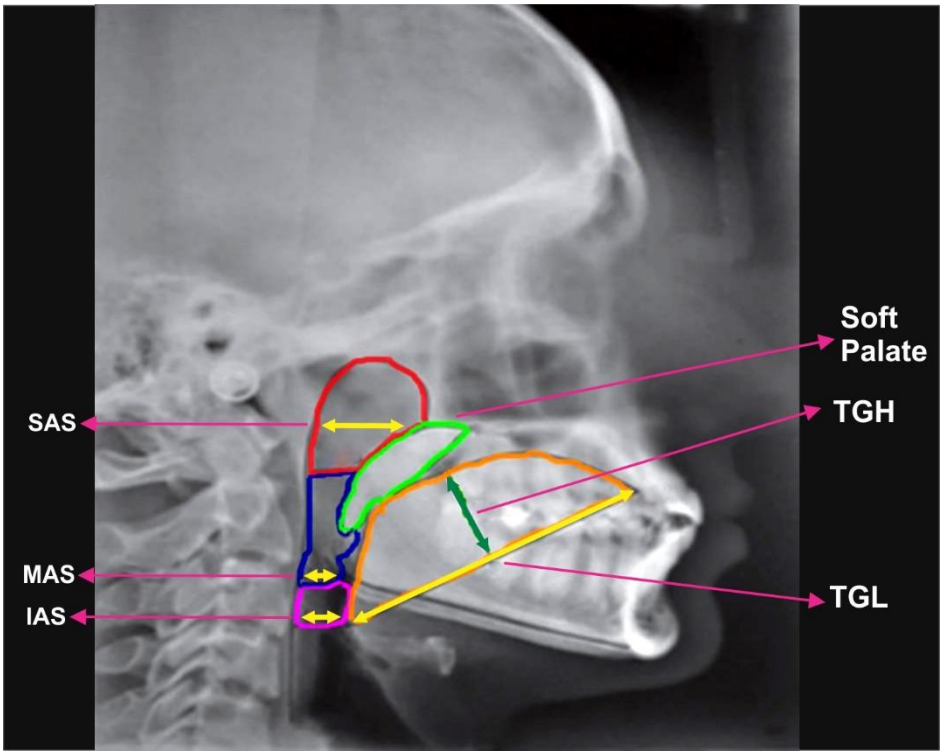
- Middle airway space (MAS):- It is measured from the point of intersection of the posterior border of the tongue and the inferior border of the mandible to the closest point on the posterior pharyngeal wall.

- Inferior airway space (IAS):- It is measured between the posterior pharyngeal wall and the point of intersection of the tongue with hyoid bone.

Tongue measurements:

- Tongue length (TGL):- It is measured between the tip of the tongue (TT) and the base of the epiglottis (Eb), the deepest point of the epiglottis.

- Tongue height (TGH):- It is the linear distance between a point on the most superior curvature of the tongue dorsum and the base of a line drawn perpendicular to the TT-V line.



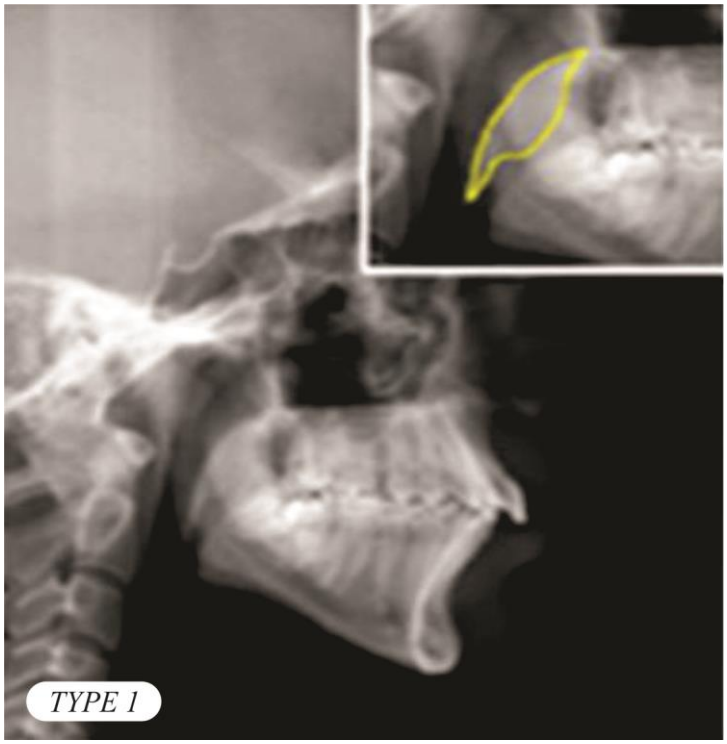
Where, SAS -Superior airway space
MAS - Middle airway space
IAS- Inferior airway space
TGL- Tongue length
TGH -Tongue height

Pharyngeal airway space and tongue measurements[5]

Soft palate shape variations:

- Type 1: Leaf shaped
- Type 2: Rat-tail shaped
- Type 3: Butt-like
- Type 4: Linear shaped.

- Type 5: S-shaped
- Type 6: Crooked appearance
- Type 7: U-shaped soft palate
- Type 8: Variants which are different from above types
- Type 9: Cone Shaped.
- Type 10: Triangular shape.
- Type 11: V shaped.



Soft palate shape variations[42]

Soft palate size measurements:

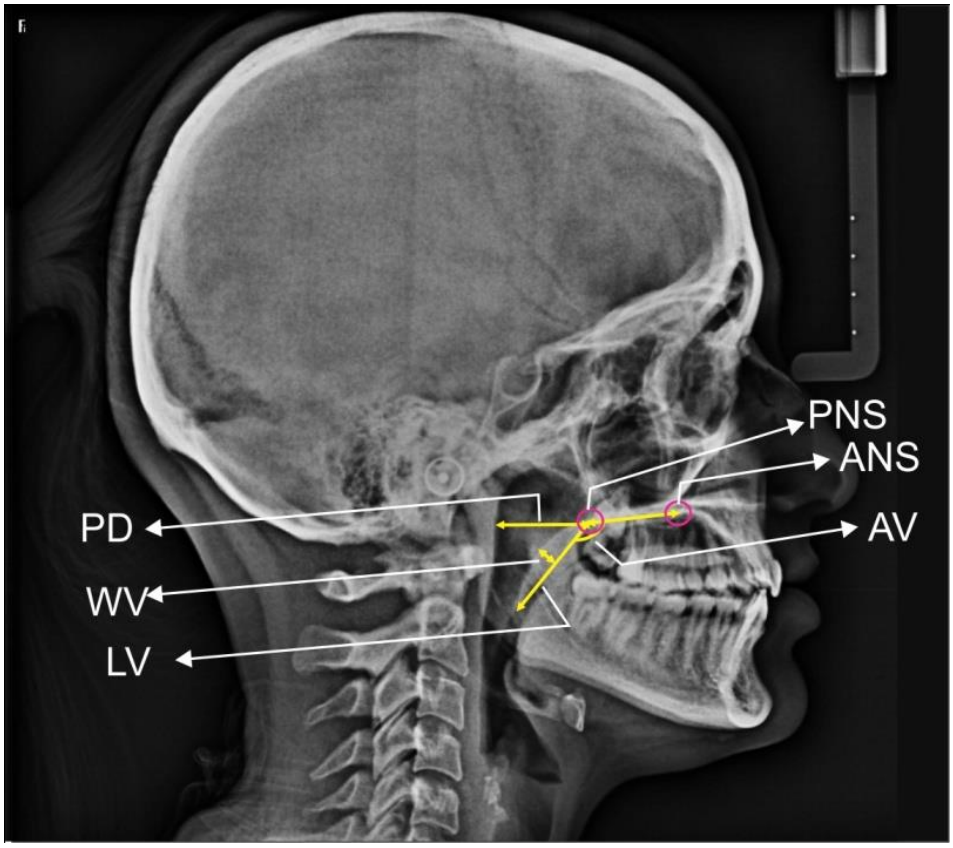
- Length of velum (soft palate) [LV]:- Linear distance measurement from posterior nasal spine to the tip of uvula of resting soft palate.

- Width of Velum (soft palate) [WV]:- Linear measurement at thickest portion of soft palate and perpendicular to its length.

- Pharyngeal Depth [PD]:- Linear measurement from the posterior surface of the nasal spine marker to the posterior pharyngeal wall along the palatal plane.

- Need's Ratio [NR] :- Division of PD by LV, PD/LV obtained at a resting position,

- Angle of Velum (soft palate) [AV]:- As angle formed between line joining (anterior nasal spine –posterior nasal spine) and line (posterior nasal spine to tip of uvula).



Soft palate size measurements [18]

Statistical methods

The data on demographic parameters like age and gender were summarized in terms of frequencies and percentages. The behavioural habits like areca nut and tobacco of subjects were also expressed in terms of frequencies and percentages. The air-way assessment parameters were expressed in terms of mean and standard deviation for each study group. The comparison of means across groups was performed using one-way analysis of variance. The paired comparison was carried out using Tukey's post-hoc test. Such a comparison was performed between different study groups. The comparison between the two groups was carried out using t-test for independent samples. The comparison of morphological variations of soft palate shape across groups was performed using Pearson's Chi-square test. Also the comparison of soft palate size was performed using one-way analysis of variance. The correlation between each airway assessment parameter and soft palate assessment parameter was obtained using Pearson's correlation coefficient.

All the analyses were performed using SPSS version 20.0 (IBM Corp) and R-3.0.0 programming tool. The statistical significance was tested at 5% level.

The formulations used were:

If x_1, x_2,…x_n are the observations on random variable X, then

A) Sample mean for a set of observations is given by

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

B) Standard deviation for a set of observations in given by

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

Where x_i = observation on each object

n = number of objects

C) Student's t-test for independent samples

The test is used for comparing the statistical significance of difference in the means of two samples. It compares the sample difference between two means in relation to the variation in the data (expressed as the standard deviation of the difference between the means).

It is given by the formula:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{s_{(\bar{x}_1 - \bar{x}_2)}}$$

where $\bar{x}_1$ and $\bar{x}_2$ are the means of sample observations of two different groups, μ_1 and μ_2 are the means of the respective populations from which the samples are derived, and $s_{(\bar{x}_1 - \bar{x}_2)}$ is the pooled sample standard deviation, which is given by:

$$s(\bar{x}_1 - \bar{x}_2) = \sqrt{\frac{s^2_{pooled}}{n_1} + \frac{s^2_{pooled}}{n_2}}$$

where

$$s^2_{pooled} = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

here s_1^2 and s_2^2 are the variance of two samples and n_1 and n_2 are the sample sizes in two groups.

If the test statistic results in a *P*-value > 0.05 (level of significance), then the null hypothesis H_0: *There is insignificant difference in the means of two groups* is accepted and the alternative hypothesis H_1: *There is significant difference in the means* is rejected. On the other hand, if *P*-value < 0.05, then the H_1 is accepted and H_0 is rejected.

D) One-way Analysis of variance

Analysis of variance (ANOVA) is used to test the significance of difference in the mean of three or more groups. The basic assumption is that the variable of interest is normally distributed in the population under study.

Method

Here the interest is to test the null hypothesis that the population means are same, i.e.

$$H_0 : \mu_1 = \mu_2 = ...\mu_m$$

against the alternative H_1 that they are not same.

Some of the statistics computed to test the hypothesis are as below:

i) Grand mean: It is the mean of set of all observations in the studied groups and is given by:

$$\bar{x}_{GM} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

ii) Total sum of squares: It is the sum of squares of each observation from the grand mean and is given by:

$$TSS = \sum_{i=1}^{N} (x_i - \bar{x}_{GM})^2$$

Total sums of squares is the sum of two components i.e., variation between groups and within groups.

iii) Between group sum of squares

$$SSB = \sum_{j=1}^{m} n_j (\bar{x}_j - \bar{x}_{GM})^2$$

iv) Within group sum of squares

$$SSW = \sum_{j=1}^{m}\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2$$

The mean sum of squares is obtained by dividing the above sum of squares with the respective degrees of freedom, i.e. N-1, p-1 and $p(n$-1).

v) F-statistic: It is the ratio of between and within mean sum of squares

$$F = \frac{MS_{Between}}{MS_{Within}}$$

If the p-value based on F-statistic is greater than 0.05, H_0 is accepted, otherwise H_1 is accepted.

vi) Tukey's post-hoc test

After performing ANOVA, if alternative hypothesis H_1 is accepted, then the subsequent interest is to determine the pair wise significance of difference in the means of study groups. This could be carried using Tukey's post-hoc test. The difference between the means of all groups are determined and compared with this critical difference called the honest significant difference (HSD). It is given by:

$$HSD = q\sqrt{\frac{MS_{within}}{n}}$$

where, q is the studentized range statistic derived from the tables, n is the sample size and the mean square value is from the ANOVA analysis. If the critical difference exceeds the absolute difference between any two sample means, then the corresponding means differ significantly.

E) Chi-square test

Let *X* and *Y* be two variables under study with *r* and *s* levels respectively; and the data on *r*×*s* levels be in the form of counts. Let the null hypothesis be that the two variables are independent. That is, knowing the levels of *X* does not help in predicting the levels of *Y*; against the alternative hypothesis that the two factors are not independent. That is, knowing the level of *X* can help in predicting levels of *Y*. To decide about the acceptance of hypothesis, the Chi-square test statistic is used which is defined as:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{s}\frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Where O_{ij} is the observed frequency count for i^{th} level of variable *X* and j^{th} level of variable *Y*. E_{ij} is the expected frequency count for same cell. The expected count is given by

$$E_{ij} = \frac{n_i \times n_j}{n}$$

Where n_i and n_j are the total counts for i^{th} level of variable *X* and j^{th} level of variable *Y*; and *n* is the total count. The calculated Chi-square value is compared with the tabulated one for (*r*-1)×(*s*-1) degrees of freedom. If the corresponding *p*-value is smaller than the pre-decided significance level, say 0.05, then we reject the null hypothesis and accept the alternative one. If the *p*-value is more than 0.05, then we accept null hypothesis.

Plate-01

Figure 1 : Armamentarium for clinical examination.

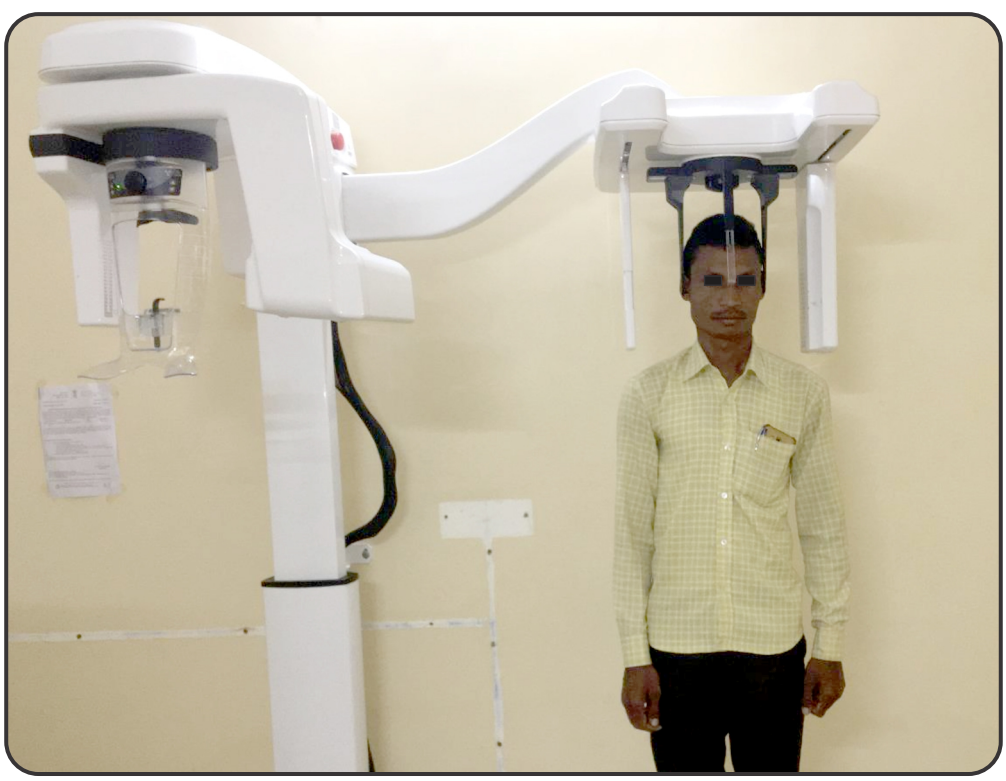


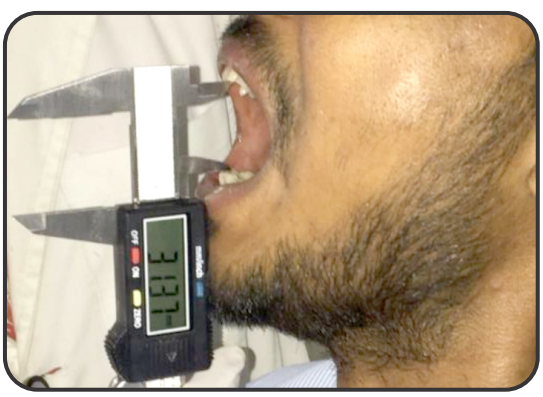
Figure 2: CS 8100 SC Carestream Digital Panoramic and Cephalometric Machine

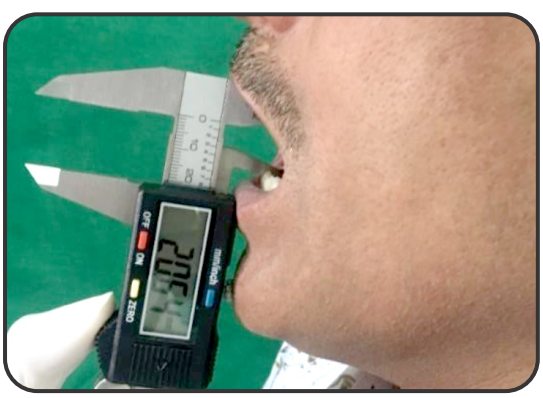
Plate-02

Figure 3: Clinical staging of OSMF (Khanna and Andrade Classification)

Group I OSMF

Group II OSMF





Group III OSMF

Group IV OSMF

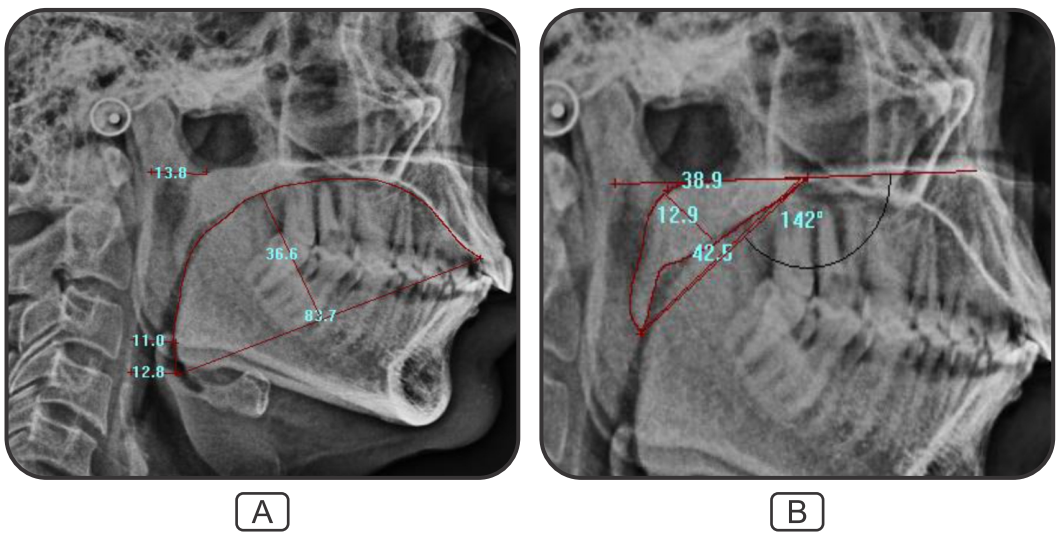


Figure 4: Lateral cephalogram showing evaluation of pharyngeal airway space and tongue (A) and soft palate (B) in Group A

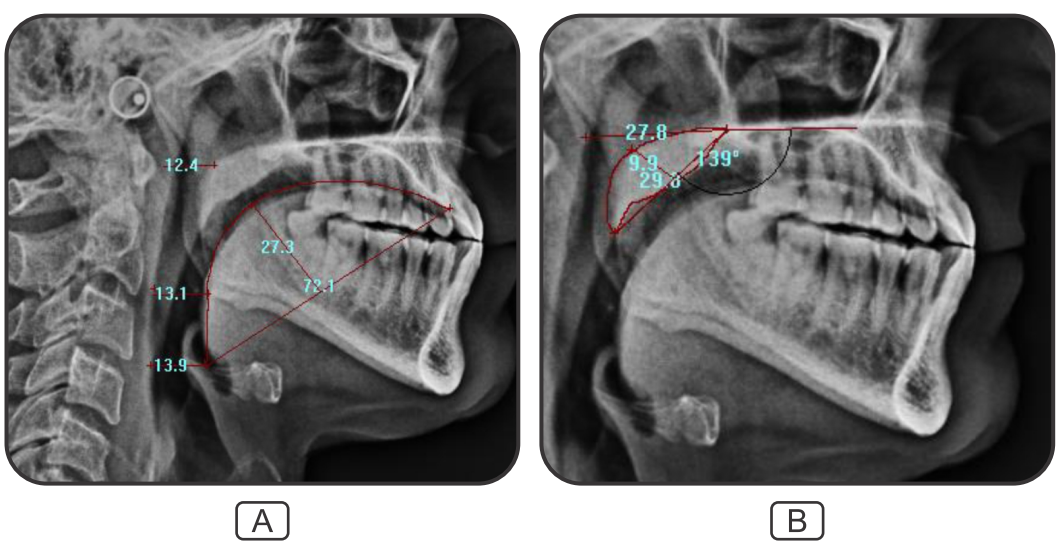


Figure 5: Lateral cephalogram showing evaluation of pharyngeal airway space and tongue (A) and soft palate (B) in Group B

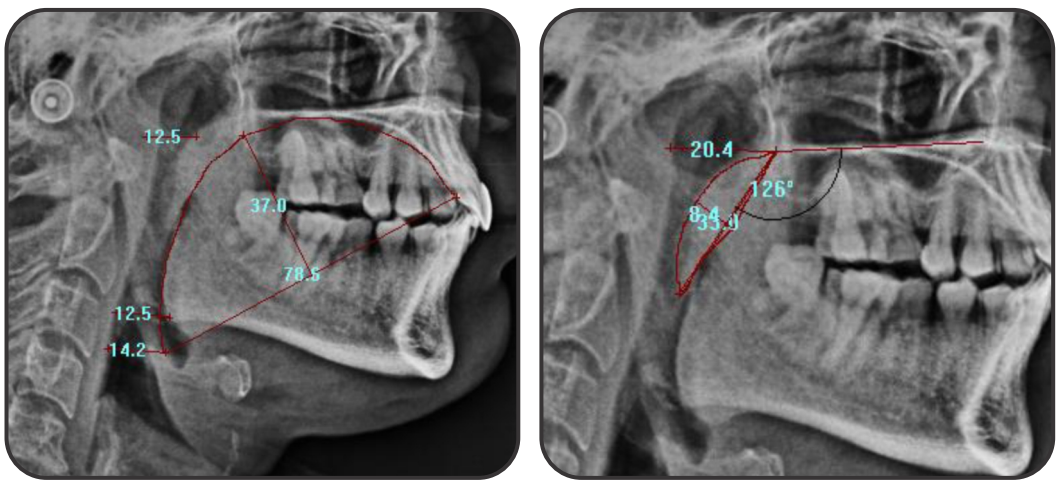


Figure 6: Lateral cephalogram showing evaluation of pharyngeal airway space and tongue (A) and soft palate (B) in Group C1

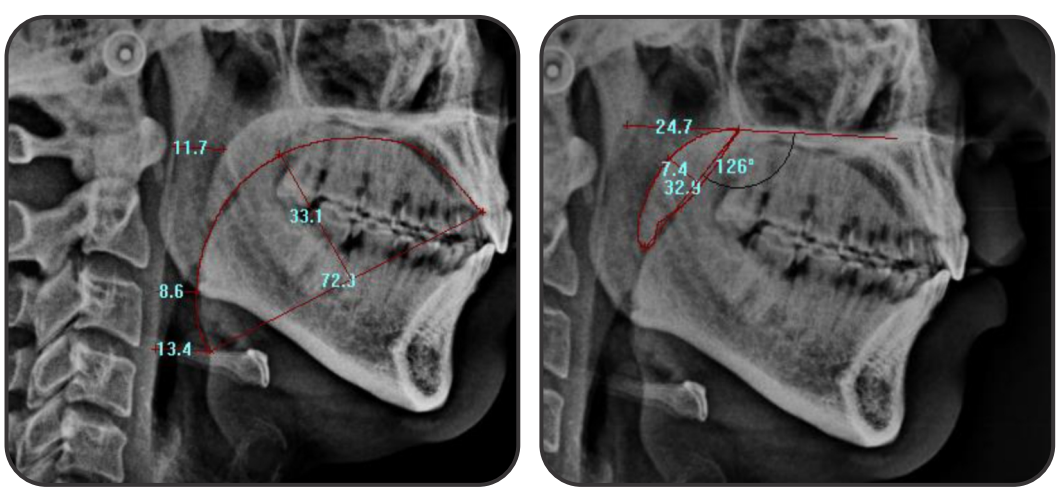


Figure 7: Lateral cephalogram showing evaluation of pharyngeal airway space and tongue (A) and soft palate (B) in Group C2

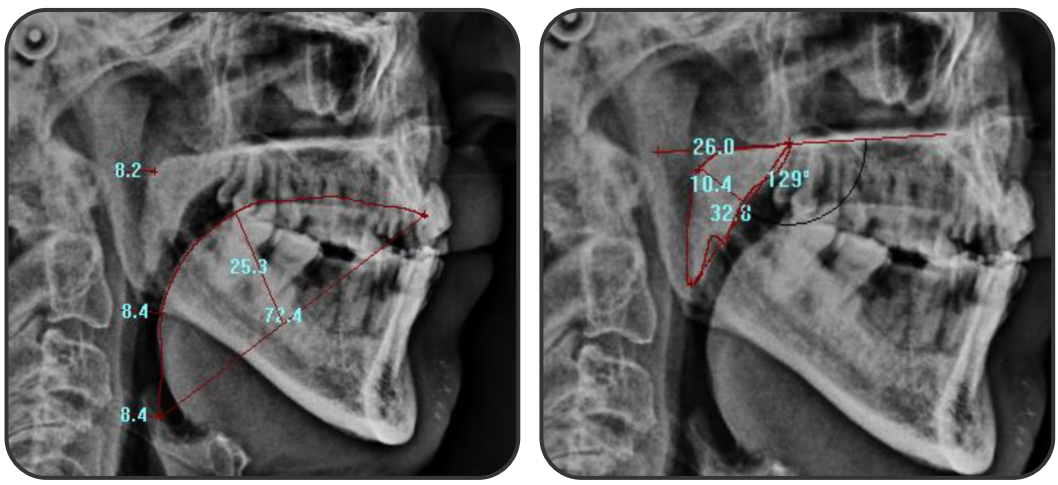


Figure 8: Lateral cephalogram showing evaluation of pharyngeal airway space and tongue (A) and soft palate (B) in Group C3

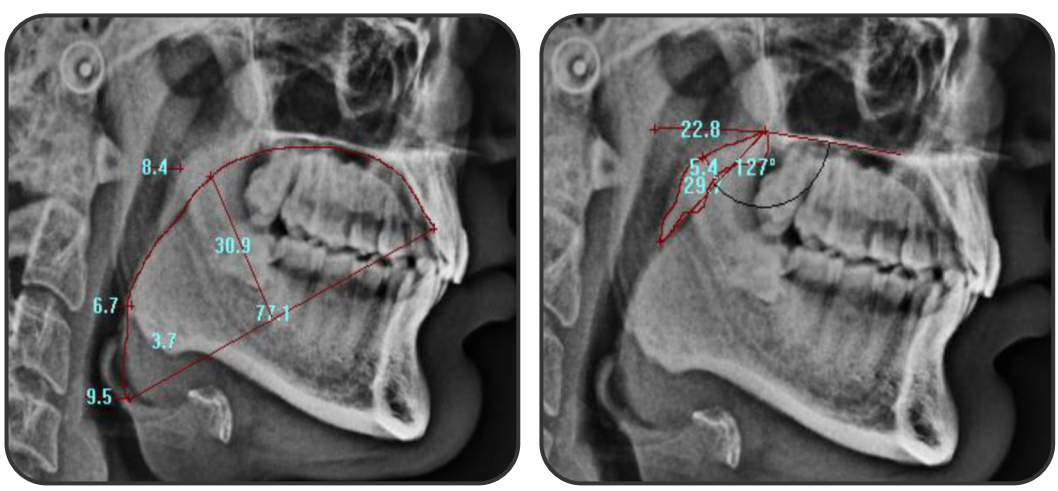


Figure 9: Lateral cephalogram showing evaluation of pharyngeal airway space and tongue (A) and soft palate (B) in Group C4

Results

A hospital based cross-sectional, observational study was undertaken to evaluate the pharyngeal airway space, tongue and morphological variations of soft palate in different stages of (OSMF) patients using digital lateral cephalogram.

Total 240 subjects were selected from the departmental OPD &were categorized in **THREE** groups.

Group A - 40 Healthy individuals with no habit & no lesion

Group B - 40 individuals with habit but no lesion

Group C - OSMF patients (as per Khanna and Andrade classification)

- C1(Group 1)- 40
- C2 (Group 2)- 40
- C3 (Group 3)- 40
- C4 (Group 4)- 40

Pharyngeal airway space, soft palate and tongue were evaluated on digital lateral cephalograms. The observations and results of study were evaluated and interpreted.

Distribution of Age

Table 1 provides the distribution of patients according to age in different study groups.The most common age group seen in the study was between 21-30 years, which was 40% in Group A, 30% in Group B, 40% in Group C1, 32.5% in Group C2, 30% in Group C3 and 45% in Group C4. The difference in the age pattern of patients across groups was statistically insignificant with a p-value of 0.349.

Distribution of Gender

Table 2 gives the distribution of patients according to gender across study groups. As per, the distribution of patients in different groups were statistically non- significant with a p-value of 0.062.

Distribution of Habit

Table 3 provides the distribution of patients according to their habits across study groups. Out of all habits, kharra consumption was seen to be frequent amongst all age groups

The consumption pattern differed significantly across groups as indicated by p-value < 0.0001.

Table 4 provides the gender-wise distribution of patients according to their habits. Among 184 males, maximum patients i.e. 128 (69.57%) had habit of kharra chewing whereas, among 56 females, 30(53.57%) females had habit of areca nut chewing.The consumption pattern differed significantly between gender as indicated by p-value < 0.0001.

Evaluation of Pharyngeal Airway Space, Soft Palate and Tongue

Table 5a gives the comparison of pharyngeal airway assessment across three groups i.e. control (Group A), with habits without lesion (Group B) and with OSMF (Group C). The mean superior airway space, middle airway space and total airway space differed significantly across three groups with a p-value < 0.0001. Tukey's post-hoc test revealed a significant difference between control and OSMF patients with $p < 0.05$ (Graph1).

Table 5b gives the comparison of airway assessment between control (Group A) and patients with habits but without lesion (Group B) using independent samples t-test. The mean superior airway space in Group A was significantly higher than Group B whereas total airway space did not show any significant change.

Table 5c gives the comparison of airway assessment between control (Group A) and patients with OSMF (Group C), using independent samples t-test. The mean superior, middle and total airway space in Group A was significantly higher than in Group C, whereas, the mean inferior airway space did not differ significantly.

Table 5d gives the comparison of airway assessment between control (Group A) and subgroups of patients with OSMF (Groups C1-C4), using one-way ANOVA. The mean superior, middle and total airway space for Group A was significantly higher than Groups C3 and C4 using Tukey's post-hoc test. Inferior airway space show statistically insignificant difference between groups (Graph2).

Table 5e gives the comparison of airway assessment between patients with habit but without lesion (Group B) and patients with OSMF (Group C) using independent

samples t-test. The mean superior, middle and total airway space in Group B was significantly higher than Group C. While, mean inferior airway space differed non-significantly.

Table 5f gives the comparison of airway assessment between patients with habit but without lesion (Group B) and sub-group of patients with OSMF (Group C1-C4) using one-way ANOVA. The mean superior, middle and total airway space for Group B was significantly higher than Groups C3 and C4 as per Tukey's post-hoc test ($p < 0.05$). Inferior airway space was found to be statistically insignificant (Graph3).

Table 5g gives the comparison of airway assessment parameters across the sub-group of patients with OSMF (Group C1-C4) using one-way ANOVA. The difference of mean superior and total airway space was statistically significant across sub-groups with a p-value < 0.0001. The mean superior, middle and total airway space for Group C1 was significantly higher than Group C4 as per Tukey's post-hoc test ($p < 0.05$). The mean for inferior airway space was statistically insignificant (Graph4).

Table 6 gives the distribution of patients as per morphological variations of soft palate shapes across the study groups. The difference in the distribution was statistically significant with a p-value < 0.0001 (Graph5).

Table 7a gives the comparison of morphological variations of soft palate size across study groups using one-way ANOVA. The mean length of soft palate was significantly different across groups with a p-value of 0.01. The pairwise comparison using Tukey's post-hoc test suggested that the mean length for Group B was significantly higher than that of Group C ($p < 0.05$). The paired analysis revealed that the mean width of soft palate, pharyngeal depth and need's ratio for Group A was significantly higher than group C ($p < 0.05$) (Graph 6).

Table 7b gives the comparison of variations of soft palate size between study Groups A and B using the independent sample t-test. The mean width of soft palate and pharyngeal depth for Group A was significantly higher than Group B. Similarly, the Need's ratio was statistically significantly different between two groups with a p-value < 0.0001. Whereas, the mean length and angle of soft palate differed with statistically insignificant p value between Group A and Group B.

Table 7c gives the comparison of variations of soft palate size between study Groups A and C using the independent sample t-test. The mean width of soft palate and pharyngeal depth for Group A was significantly higher than Group Cwith a p-value < 0.0001. The mean need's ratio for Group A was significantly higher than Group Cwith a p-value of 0.002. The mean length and angle of soft palate differed between Group A and Group C with insignificant p value.

Table 7d gives the comparison of variations of soft palate size across control and OSMF sub-groups according to stages, using one-way ANOVA. The paired analysis revealed that the mean width of soft palate, pharyngeal depth and the Need's ratio for Group A was significantly higher than Groups C3 and C4 ($p < 0.05$). The mean length and angle of soft palate differed insignificantly between control and subgroups of OSMF (Graph 7).

Table 7e gives the comparison of variations of soft palate size between study Groups B and C using the independent sample t-test. The mean length of soft palate and pharyngeal depth for Group B was significantly higher than Group C. Whereas mean width and angle of soft palate along with need's ratio differed statistically insignificant between Group B and Group C (OSMF).

Table 7f gives the comparison of variations of soft palate (size) across patients with habit but without lesion (Group B) and OSMF sub-groups (C1-C4) according to stages, using one-way ANOVA. The paired analysis revealed that the mean length of soft palate and pharyngeal depth for Group B was significantly higher than Groups C3 and C4 ($p < 0.05$). Mean width of soft palate differed between groups with p value of 0.760. Similarly, need's ratio and angle of soft palate differed with statistically insignificant p value between the groups (Graph 8).

Table 7g gives the comparison of variations of soft palate (size) across patients with OSMF (C1-C4), using one-way ANOVA. The mean pharyngeal depth was significantly different across groups with a p-value < 0.0001. Tukey's post-hoc test revealed that the mean for Group C1 was significantly higher than Groups C3 and C4 ($p < 0.05$). Across the subgroups of OSMF, mean length, width and angle of soft palate along with Need's ratio differed with insignificant p value (Graph 9).

Table 8a gives the comparison of tongue parameters across three groups i.e. control (Group A), with habits without lesion (Group B) and with OSMF (Group C). The tongue height differed significantly across groups as indicated by a p-value of 0.012. The mean difference between group B and group C was statistically significant as indicated by Tukey's post-hoc test ($p < 0.05$). Whereas, tongue length differed across three groups with p value of 0.079, which is statistically insignificant (Graph 10).

Table 8b gives the comparison of tongue parameters between control (Group A) and patients with habits but without lesion (Group B) using independent samples t-test. The mean tongue length in Group B was found to be significantly higher than Group A.

Table 8c gives the comparison of tongue parameters between control (Group A) and patients with OSMF (Group C), using independent samples t-test. The mean tongue length and height were statistically insignificant between two groups.

Table 8d gives the comparison of tongue parameters between control (Group A) and subgroups of patients with OSMF (Groups C1-C4), using one-way ANOVA. Mean tongue length and height were found to be statistically insignificant between Group A and subgroups of Group C (Graph 11).

Table 8e gives the comparison of tongue parameters between patients with habit but without lesion (Group B) and patients with OSMF (Group C) using independent samples t-test. The mean tongue length for Group B was significantly higher than Group C while the mean tongue height did not show statistically significant difference.

Table 8f gives the comparison of tongue parameters between patients with habit but without lesion (Group B) and sub-group of patients with OSMF (Group C1-C4) using one-way ANOVA. Mean tongue length and height were statistically insignificant between Group B and subgroups of Group C (Graph 12).

Table 8g gives the comparison of tongue parameters across the sub-group of patients with OSMF (Group C1-C4) using one-way ANOVA. Tongue length and height did not show statistically significant difference across the sub-group of patients with OSMF (Graph 13).

CORRELATION ANALYSIS

The scatter plots (Panel A and B) show the relationship between total airway space and soft palate parameters in all groups and in four sub-groups of OSMF, using Pearson's correlation coefficient.

1. Total Airway Space vs. Length of soft palate

In control group, the total airway space and length of soft palate had statistically significant weakly positive correlation. The Groups B,C and C4 shows statistically insignificant weakly positive correlation whereas Group C1, C2 and C3 shows insignificant weakly negative correlation (Graph 14).

2. Total Airway Space vs. Width of soft palate

Groups A, B and C2 shows statistically insignificant weakly positive correlation. In group C3, the total airway space and width of soft palate had statistically significant weakly negative correlation and groups C, C1 and C4 shows insignificant weakly negative correlation (Graph 15).

3. Total Airway Space vs. Pharyngeal depth

In control group, the total airway space and pharyngeal depth had statistically significant weakly positive correlation. Further, in group B and C shows moderately and weakly positive correlations respectively, with p-values < 0.0001 each. Group C2 and C4 shows statistically significant weakly positive correlation. Whereas groups C1 and C3 show insignificant weakly positive correlation (Graph 16).

4. Total Airway Space vs. Angle of soft palate

In control group, the total airway space and angle of soft palate had statistically significant weakly positive correlation. Group C4 shows statistically insignificant

weakly negative correlation. Whereas, groups B, C1, C2 and C3 show weakly positive correlation which was found to be statistically insignificant (Graph 17).

Discussion

In India, consumption of tobacco and areca nut products in different forms like kharra, gutkha, etc has increased within last few decades and are associated with increased risk of potentially malignant conditions like OSMF and consequently oral cancer. Malignant transformation associated with OSMF has been documented as 7-12%.[50] OSMF is of great concern, as it poses individual not only for development of malignancy but also alters the lifestyle pattern over a period of time.

Oral submucous fibrosis (OSMF) is the most common premalignant condition seen in Indian population. Clinically it affects almost any part of oral cavity. It may involve larynx, pharynx and oesophagus. Due to epithelial atrophy and fibroelastic changes in lamina propria, there is stiffness of oral mucosa, reduced mouth opening, restricted tongue movements and difficulty in swallowing and tinnitus.[3] These patients may show increased incidence of asthma, liver fibrosis, hypertension, etc.

It is assumed that with the progression of OSMF, there are increased chances of involvement of posterior fibro vascular part of the palate, soft palate and pharynx.

Also, it poses difficulties during intubation procedures in advanced cases. So, it is important to assess changes in morphology of pharyngeal airway in OSMF patients.

OSMF patients clinically manifests altered morphology of uvula as well as tongue and their restricted functions due to fibrosis of overlying mucosa in soft palate and floor of mouth. So, it is also important to evaluate the changes in velar morphology and tongue dimensions that occur at different stages of OSMF.

There is majority of population who remains asymptomatic even after consumption of tobacco and areca nut products routinely. But, there could have been possibility of involvement of oral structures before clinical manifestation in these individuals. Thus, in the present study the individuals with habit but without lesion are included as one of the group for assessment of pharyngeal airway, soft palate and tongue.

Various studies have documented use of lateral cephalogram successfully for the analysis of pharyngeal airway space, soft palate and tongue.

Studies documented in the literature evaluated pharyngeal airway space with soft tissue like tongue on lateral cephalogram in individuals with malocclusion and OSA.[5,23,32,34,39,41,43,46,47,49]

Soft palate was assessed on lateral cephalogram in obstructive sleep apnea patients[5,22], in skeletal class II malocclusion with different facial patterns[24,36] in healthy individuals[23,25,28,29,30,33,37,42] and in OSMF patients.[12,13,14,1,16,17,18,20,21]

Due to advantages like easy availability, low cost and less exposure lateral cephalogram is widely used as compared to the advanced imaging modalities like CT, MRI, CBCT.

Various authors [4,22,26,27,31,35,38,40,48,44,45]compared the efficacy of two dimensional lateral cephalogram with three dimensional modalities like CBCT, CT, MRI and concluded that the lateral cephalogram can be used with better efficacy for linear measurements of pharyngeal airway space.

The present study was planned to evaluate pharyngeal airway space, tongue along with soft palate in OSMF patients as well as individuals with habit without any lesion using digital lateral cephalogram.

In the present study, pharyngeal airway space and soft palate were estimated in total 240 subjects with homogenous distribution (n=40) in all groups i.e. healthy individuals without habit and lesion (Group A), healthy individuals with habit but without lesion (Group B), OSMF patients (Group C), which is subdivided in further 4 groups i.e. Group C1, Group C2, Group C3 and Group C4.

In the present study, age range for controls, with and without habit was 10-70 years which is in accordance with the age reported by previous studies.[12,13,16,18,20] The maximum number of subjects with habits and OSMF patients were seen in 2nd and 3rd decade which indicate its higher incidence in the younger age group with insignificant gender distribution. (Table1 and 2) These results are in accordance with the studies by **Hazarey VK et al[51], Kumar S[52],Kathiriya D et[53], More CB et al[56]**.Whereas,it was different from the findings of **Deshmukh R et al[13]and Alok A et al[21]**who reported increased prevalence in the age range of 31-40 years.

In order to assess changes in individuals with habit without any lesion, distribution of habits was considered. Out of all habits, kharra consumption was most frequent in all

age groups and was found to be the most commonly consumed by males. Whereas, areca nut consumption was more common among female patients (Table 3 & 4). These results are similar to the prior studies.[17,51,52,53,54,55]

In the present study, superior airway in control group was found to be 15.1 mm which was similar to the studies by **Gupta et al[34]**, **Ansar J et al[41]**, **Kaur S et al[5],Tarkar J et al[43] and Sprenger R et al[46]**who assessed airway in healthy individuals.

In the present study, the mean total, superior and middle airway space decreased in habit and OSMF group as compared to control (Table 5a). It was also decreased in OSMF patients in comparison with habit group (Table 5e). These spaces showed progressive reduction within subgroups of OSMF (Table 5g).This can be attributed to difficulty in swallowing and contributing factor for difficult intubation during surgical management in advanced cases of OSMF. Similar findings are reported by **Sujee C et al[9], Rachana ND[11]**and**Eipe N[8].**

Gupta S[34]and**Tarkar J et al[43]**found reduced upper oropharyngeal width in vertical skeletal pattern as compared to horizontal skeletal pattern. **Mani P et al[39]** also noted narrow upper pharyngeal airway width in the hyperdivergent facial pattern as compared to normodivergent and hypodivergent facial pattern. Dimensional variations due to skeletal malocclusion was avoided in the present study, as individuals with only Angle's class I malocclusion were included.

The mean inferior airway space did not show significant reduction between control and OSMF patients and within OSMF subgroups (Table 5a).

Mani P et al[39] showed reduced pharyngeal airway can act as a predisposing factor for OSA. It can be suggested from the findings of present study that the reduced airway in OSMF and habit group may lead to development of OSA in these individuals.

Morphological variations of soft palate were assessed according to shape and size by various authors in healthy individuals[25,30,42] while, **Verma P et al**[33]**and Khoja A**[19]evaluated these variationsalong with pharyngeal depth and need's ratio. Whereas few studies had evaluated only shape variationsin healthy individuals[21,28,29,37] and in different types of malocclusion[36.]

Morphological variations of soft palate according to shape and size were evaluated. in obstructive sleep apnea syndrome[21,22]andin OSMF patients.[12,13,15,16,17,20,21]

In the present study, eleven types of soft palate shapes were reported which is in accordance with **Nagaraj T et al**[42] **(**Table 6, Graph 5).

In our study, the most common type of soft palate seen in control group was type 1 i.e. leaf shaped, which is in accordance with the results stated by certain authors.[13,25,29,30,33,37,42]

While, it is not in accordance with the findings of studies by **Samdani D**[36]and **Alok A et al**[21]**,** where **Samdani D**[36]found rat tail type (type2) in class I malocclusion, leaf-shaped soft palate (type1) in class II malocclusion and crooked shaped soft palate (type6) in class III malocclusion and **Alok A et al**[21]found leaf-type soft palate (tyep1) in OSA patients.

In the present study individuals with habit showed type 1 soft palate (table 6) which is not in accordance with **Deshmukh R et al**[13]who found rat tail type (type 2) to be common.

In the present study, while evaluating soft palate in subgroups of OSMF, type 1 was most common in early OSMF groups (C1 & C2) and with the advancement of the disease, it altered from type 1 to type 3 i.e. butt like and type 6 i.e. crooked shape (Table 6, Graph 5). These findings are in accordance with studies reported in the literature.[12,13,15,16,17,18,20,21]

Soft palate has an important role in speech and swallowing. Any alterations in shape, size and length of soft palate may lead to increased risk of OSA.[57] So, altered shape from type 3 to type 6 found in OSMF patients of present study can be considered as one of the risk factor for development of OSA in these patients.

In our study, along with shape variations of soft palate (velum),size variations like length, width, angle, pharyngeal depth and need's ratio were assessed.

In the present study, mean length of velum was 31.71 mm in control. It was reduced significantly in OSMF patients when compared with habit but non -significant difference was seen with control (Tables 7a-g). This is similar to the findings by many authors. [13,16,17,18,20]

In present study, the width of velum in control was 10.4mm and reduced significantly in habit and in OSMF patients (Tables 7a-g), which is not in accordance with prior studies.[13,16,17,18,20]

In the present study, pharyngeal depth and need's ratio in control group were 32.03mm and 1.02 respectively (Tables 7a-g). It was found to be significantly reduced in habit and OSMF group, which is not in accordance with **Nerkar A et al[18].**

In the present study the angle of soft palate in control and habit group was 130.9° and 129.1°and was found to be decreased in OSMF group as compared to control (Tables 7a-g), which is in accordance with finding by **Nerkar A et al[18].**

The above findings of soft palate size and shapes in the present study can be considered as contributing factor for clinically altered morphology of soft palate in OSMF patients.

The uniqueness of present study is that the correlation analysis was also done between total airway space and dimensions of soft palate in all groups and in four sub-groups of OSMF.

In the present study, in control all the parameters of soft palate except width showed significant weakly positive correlation with total airway space, whereas width showed insignificant weakly positive relation (Graph 14-17).

In OSMF and habit group, pharyngeal depth was found to be significant positive correlation with total airway, while length, width and angle of soft palate showed insignificant negative correlation (Graph 14-17).

The above findings suggests that due to habits and OSMF, there were alterations at soft palate and airway space region seen in study groups.

Tongue dimensions are studied in individuals with OSA and malocclusion by various authors[32,34,41,42,44] but, there is no literature available for the same in OSMF patients.

In the present study, tongue dimensions of control group was similar to the findings obtained **by Tarkar J[43], Kaur et al[5]** while, it is slightly less as reported by **Daraze et al[49]**. In the progression of OSMF, functions of the tongue gets affected like restricted movements and speech defect.

In the present study, tongue height was increased in OSMF and in habit group as compared to control (Table 8a). Whereas tongue length was decreased significantly in OSMF as compared to habit group (Table 8e). The above findings in the present study can be considered as contributing factor for clinical manifestations of restricted tongue functions.

Increased tongue height as seen in our study may lead to increase in its volume and predispose the individual to OSA as documented by **Barrera J et al[48].**

Thus, in the present study total airway space was found to be reduced in habit and OSMF patients compared to control. Pharyngeal space was reduced progressively with the severity of OSMF. Airway and soft palate correlations were also seen. Soft palate showed alterations in morphology (shape and size) along with tongue dimensions in the study groups. Above findings may contribute to develop risk of OSA in these patients. So, oropharyngeal region in every individual with habit and OSMF should be examined thoroughly.

Conclusion

The present study was a hospital based cross sectional study which was carried out in the Department of Oral Medicine and radiology and Department of Orthodontics and Dentofacial Orthopaedics.

A total of 240 subjects were selected from departmental OPD and divided into three group's i.e. healthy subjects without habit (Group A), healthy subjects with habit (Group B), OSMF patients (Group C). It was further subdivided into four groups i.e. Group C1, Group C2, Group C3 and Group C4. Digital lateral cephalograms were taken for each subject from each group.

The present study was planned to evaluate changes in pharyngeal airway space and soft palate in OSMF patients. Along with their morphological variations, correlation

between these parameters were also assessed and compared with healthy individuals and with habits.

From the results of the present study it can be inferred that:

- The age range for subjects with habits and OSMF was 21-30 years. This suggests younger age group is involved in habits as well as in OSMF.
- Male predominance was seen in study population.
- Kharra was found to be most commonly consumed product in males whereas, females consume areca nut more frequently.
- The mean superior, middle and total airway space was significantly reduced in habit and OSMF group as compared to control.
- The mean superior, middle and total airway space was significantly reduced among OSMF sub- groups.
- In assessment of soft palate shape morphology, Type 1 i.e. leaf shaped soft palate was most commonly seen in control and individuals with habit.
- With the advancement of OSMF, type of soft palate changes. From type 1 in initial stages (C1 and C2), it alters to become type 3 and 6 in advanced stages (C3 and C4).
- While assessing dimensional variations, it was found that Length of soft palate has reduced significantly in OSMF patients when compared with habit but non -significant difference was seen with control.
- Width of soft palate, pharyngeal depth and need's ratio was significantly reduced in habit and OSMF group.
- Angle of soft palate was also found to be reduced in OSMF group as compared to control.

- In healthy individuals, significant weakly positive correlation was seen between total airway space and parameters of soft palate except width.
- Habit and OSMF groups show significant positive correlation of pharyngeal depth with total airway space.
- While assessment of tongue, tongue height was seen to be increased in OSMF and in habit group as compared to control.
- Tongue length was decreased significantly in OSMF as compared to habit group.

Limitations and future prospective

The present study evaluated pharyngeal airway space and soft palate morphology using digital lateral cephalograms. As it is 2- dimensional modality, the area and volume measurements cannot be done. So, for volumetric evaluation use of advanced imaging modality like CBCT or MRI is advocated.

In our study, 40 participants were considered in each group with wide age range and uneven distribution of both genders. So, the age and gender wise comparison cannot be done for evaluation of airway and soft palate. So, further studies are recommended with uniformity in age and gender with larger sample size.

Easy availability, cost efficiency and less exposure makes lateral cephalogram a simple method to ascertain the effects of disease. It can very well used as evidence in individuals with habit and prevent its further progression into disease.

It is one of the study to evaluate and correlate pharyngeal airway space and soft palate in individuals with habit and OSMF patients.

The findings from the study states that there are alterations in airway and soft palate due to habit and OSMF. So, it indicates the involvement of these structures during course of the disease and its clinical manifestations. Also, its involvement is dependent on severity of disease. So, every OSMF patient should be screened for evaluation of airway.

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Tables

Table 1: Distribution of patients according to age categories

Age (in years)	Group A (n=40)		Group B (n=40)		Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
10-20	5	12.50	2	5.00	0	0.00	6	15.00	2	5.00	1	2.50	
21-30	16	40.00	12	30.00	16	40.00	13	32.50	12	30.00	18	45.00	
31-40	10	25.00	11	27.50	13	32.50	11	27.50	15	37.50	10	25.00	0.349
41-50	6	15.00	7	17.50	9	22.50	4	10.00	8	20.00	8	20.00	(NS)
51-60	1	2.50	7	17.50	2	5.00	5	12.50	3	7.50	3	7.50	
61-70	2	5.00	1	2.50	0	0.00	1	2.50	0	0.00	0	0.00	

*Obtained using Chi-square test; NS: Not significant

Table 2: Distribution of patients according to gender

Gender	Group A (n=40)		Group B (n=40)		Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Male	24	60.00	28	70.00	32	80.00	34	85.00	33	82.50	33	82.50	0.062 (NS)
Female	16	40.00	12	30.00	8	20.00	6	15.00	7	17.50	7	17.50	

*Obtained using Chi-square test; NS: Not significant

Table 3: Comparison of patients habits according to age

Habits	Age (in years)												P-value*
	10-20 (n=16)		21-30 (n=88)		31-40 (n=71)		41-50 (n=42)		51-60 (n=21)		61-70 (n=2)		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
None	5	31.25	17	19.32	11	15.49	6	14.29	1	4.76	0	0.00	**< 0.0001**
Areca nut	0	0.00	10	11.36	10	14.08	8	19.05	2	9.52	0	0.00	
Areca nut+ tobacco	0	0.00	0	0.00	1	1.41	2	4.76	0	0.00	0	0.00	
Kharra	11	68.75	59	67.05	46	64.79	9	21.43	4	19.05	0	0.00	
Kharra+ areca nut	0	0.00	1	1.14	0	0.00	2	4.76	4	19.05	1	50.00	
Kharra+ tobacco & lime	0	0.00	0	0.00	2	2.82	14	33.33	5	23.81	1	50.00	
Kharra+ tobacco & lime+ bidi	0	0.00	0	0.00	0	0.00	0	0.00	1	4.76	0	0.00	
Kharra+ tobacco+ bidi	0	0.00	0	0.00	0	0.00	0	0.00	1	4.76	0	0.00	
Kharra+tobacco	0	0.00	1	1.14	1	1.41	1	2.38	3	14.29	0	0.00	

*Obtained using Chi-square test; bold value indicated significance

Table 4: Comparison of patients habits according to gender

Habits	Male (n=184)		Female (n=56)		P-value*
	No.	%	No.	%	
None	24	13.04	16	28.57	**< 0.0001**
areca nut	0	0.00	30	53.57	
areca nut + tobacco	0	0.00	3	5.36	
Kharra	128	69.57	1	1.79	
Kharra + areca nut	4	2.17	4	7.14	
Kharra + tobacco & lime	21	11.41	1	1.79	
Kharra + tobacco & lime + bidi	1	0.54	0	0.00	
Kharra + tobacco+ bidi	1	0.54	0	0.00	
Kharra + tobacco	5	2.72	1	1.79	

*Obtained using Chi-square test; bold value indicated significance

Table 5: Comparison of evaluation of pharyngeal airway space

Table 5a: Comparison of evolution of pharyngeal airway space across three groups

Airway Assessment	Group A (n=40)		Group B (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	Mean	SD	
Superior airway space (mm)	15.18	2.10	13.47	2.86	11.06	2.78	**< 0.0001**
Middle airway space (mm)	13.12	2.17	12.76	2.94	10.82	3.14	**< 0.0001**
Inferior airway space (mm)	13.12	2.08	12.65	3.09	12.80	15.51	0.985
Total airway space (mm)	41.41	5.90	38.87	7.37	33.58	7.69	**< 0.0001**

*Obtained using ANOVA; bold value indicated statistical significance

Table 5b: Comparison of evaluation of pharyngeal airway space between Group A and B

Airway Assessment	Group A (n=40)		Group B (n=40)		P-value*
	Mean	SD	Mean	SD	
Superior airway space (mm)	15.18	2.10	13.47	2.86	**0.003**
Middle airway space (mm)	13.12	2.17	12.76	2.94	0.538
Inferior airway space (mm)	13.12	2.08	12.65	3.09	0.422
Total airway space (mm)	41.41	5.90	38.87	7.36	0.093

*Obtained using Independent t-test; Bold value indicated significance

Table 5c: Comparison of evaluation of pharyngeal airway space Group A and C

Airway Assessment	Group A (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	
Superior airway space (mm)	15.18	2.10	11.06	2.78	**< 0.0001**
Middle airway space (mm)	13.12	2.17	10.82	3.14	**< 0.0001**
Inferior airway space (mm)	13.12	2.08	12.80	15.51	0.896
Total airway space (mm)	41.41	5.90	33.58	7.69	**< 0.0001**

*Obtained using Independent t-test; Bold value indicated significance

Table 5d: Comparison of evaluation of pharyngeal airway space across groups

Airway Assessment	Group A (n=40)		Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Superior airway space (mm)	15.18	2.10	13.06	2.87	11.56	2.46	10.22	2.05	9.40	2.26	**< 0.0001**
Middle airway space (mm)	13.12	2.17	12.35	3.66	11.10	2.67	9.90	3.03	9.93	2.55	**< 0.0001**
Inferior airway space (mm)	13.12	2.08	13.11	3.91	11.81	2.21	15.53	30.67	10.74	2.45	0.619
Total airway space (mm)	41.41	5.90	38.52	9.34	34.47	5.64	31.28	6.42	30.07	6.11	**< 0.0001**

*Obtained using ANOVA; Bold value indicated significance

Table 5e: Comparison of evaluation of pharyngeal airway space between Group B and C

Airway Assessment	Group B (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	
Superior airway space (mm)	13.47	2.86	11.06	2.78	**< 0.0001**
Middle airway space (mm)	12.76	2.94	10.82	3.14	**< 0.0001**
Inferior airway space (mm)	12.65	3.09	12.80	15.51	0.951
Total airway space (mm)	38.87	7.36	33.58	7.69	**< 0.0001**

*Obtained using Independent t-test; Bold value indicated significance

Table 5f: Comparison of evaluation of pharyngeal airway space across all groups

Airway Assessment	Group B		Group C1		Group C2		Group C3		Group C4		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Superior airway space (mm)	13.47	2.86	13.06	2.87	11.56	2.46	10.22	2.05	9.40	2.26	**< 0.0001**
Middle airway space (mm)	12.76	2.94	12.35	3.66	11.10	2.67	9.90	3.03	9.93	2.55	**< 0.0001**
Inferior airway space (mm)	12.65	3.09	13.11	3.91	11.81	2.21	15.53	30.67	10.74	2.45	0.624
Total airway space (mm)	38.87	7.36	38.52	9.34	34.47	5.64	31.28	6.42	30.07	6.11	**< 0.0001**

*Obtained using ANOVA; Bold value indicated significance

Table 5g: Comparison of evaluation of pharyngeal airway space across OSMF patients

Airway Assessment	Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Superior airway space (mm)	13.06	2.87	11.56	2.46	10.22	2.05	9.40	2.26	**< 0.0001**
Middle airway space (mm)	12.35	3.66	11.10	2.67	9.90	3.03	9.93	2.55	**0.001**
Inferior airway space (mm)	13.11	3.91	11.81	2.21	15.53	30.67	10.74	2.45	0.551
Total airway space (mm)	38.52	9.34	34.47	5.64	31.28	6.42	30.07	6.11	**< 0.0001**

*Obtained using ANOVA; Bold value indicated significance

Table 6: Comparison of Morphological variations of soft palate (Shape) across all groups

Soft palate shapes	Group A (n=40)		Group B (n=40)		Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Leaf Shape	22	55.00	18	45.00	24	60.00	17	42.50	6	15.00	9	22.50	**< 0.0001**
Rat-tail shaped	6	15.00	5	12.50	5	12.50	0	0.00	3	7.50	5	12.50	
Butt-like	9	22.50	5	12.50	7	17.50	9	22.50	10	25.00	7	17.50	
Linear shaped	2	5.00	1	2.50	0	0.00	0	0.00	0	0.00	0	0.00	
S-shaped	1	2.50	1	2.50	0	0.00	0	0.00	0	0.00	1	2.50	
Crooked appearance	0	0.00	3	7.50	1	2.50	1	2.50	10	25.00	11	27.50	
U-shaped soft palate	0	0.00	4	10.00	1	2.50	7	17.50	8	20.00	7	17.50	
Variants which are different from above types	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	0	0.00	
Cone shaped	0	0.00	1	2.50	0	0.00	2	5.00	0	0.00	0	0.00	
Triangular shape	0	0.00	2	5.00	0	0.00	4	10.00	1	2.50	0	0.00	
V-shaped	0	0.00	0	0.00	1	2.50	0	0.00	2	5.00	0	0.00	

*Obtained using Chi-square test; Bold value indicated significance

Table 7 : Comparison of Morphological variations of soft palate (size)

Table 7a: Comparison of Morphological variations of soft palate (size) across three groups

Morphological variations of soft palate	Group A (n=40)		Group B (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	Mean	SD	
Length of velum (mm)	31.71	2.54	33.11	3.99	30.72	4.94	**0.010**
Width of velum (mm)	10.41	1.56	8.94	2.42	8.57	1.88	**< 0.0001**
Pharyngeal depth (mm)	32.03	2.51	29.42	4.02	26.20	3.78	**< 0.0001**
The Need's Ratio (mm)	1.02	0.08	0.89	0.13	0.86	0.15	**< 0.0001**
Angle of velum (mm)	130.90	4.04	129.13	4.89	130.23	6.39	0.383

*Obtained using ANOVA; Bold value indicated significance

Table 7b: Comparison of Morphological variations of soft palate (size) between Group A &B

Morphological variations of soft palate	Group A (n=40)		Group B (n=40)		P-value*
	Mean	SD	Mean	SD	
Length of velum (mm)	31.71	2.54	33.11	3.99	0.066
Width of velum (mm)	10.41	1.56	8.94	2.42	**0.002**
Pharyngeal depth (mm)	32.03	2.51	29.42	4.02	**0.001**
The Need's Ratio (mm)	1.02	0.08	0.89	0.13	**< 0.0001**
Angle of velum (mm)	130.90	4.04	129.13	4.89	0.081

*Obtained using Independent t-test; Bold value indicated significance

Table 7c: Comparison of Morphological variations of soft palate (size) between Group A &C

Morphological variations of soft palate	Group A (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	
Length of velum (mm)	31.71	2.54	30.72	4.94	0.223
Width of velum (mm)	10.41	1.56	8.57	1.88	**< 0.0001**
Pharyngeal depth (mm)	32.03	2.51	26.20	3.78	**< 0.0001**
The Need's Ratio (mm)	1.02	0.08	0.86	0.15	**0.002**
Angle of velum (mm)	130.90	4.04	130.23	6.39	0.529

*Obtained using Independent t-test; Bold value indicated significance

Table 7d: Comparison of Morphological variations of soft palate (size) across groups

Morphological variations of soft palate	Group A (n=40)		Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Length of velum (mm)	31.71	2.54	32.38	4.34	30.38	4.01	30.00	5.53	30.13	5.49	0.070
Width of velum (mm)	10.41	1.56	8.59	1.94	8.78	1.56	8.54	1.91	8.38	2.12	**< 0.0001**
Pharyngeal depth (mm)	32.03	2.51	27.96	4.16	26.75	3.55	25.64	2.97	24.46	3.57	**< 0.0001**
The Need's Ratio (mm)	1.02	0.08	0.86	0.10	0.89	0.16	0.87	0.17	0.83	0.15	**< 0.0001**
Angle of velum (mm)	130.90	4.04	131.45	6.65	130.40	6.70	130.25	6.21	128.83	5.95	0.371

*Obtained using ANOVA; bold value indicated significance

Table 7e: Comparison of Morphological variations of soft palate (size) between Group B and C

Morphological variations of soft palate	Group B (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	
Length of velum (mm)	33.11	3.99	30.72	4.94	**0.005**
Width of velum (mm)	8.94	2.42	8.57	1.88	0.229
Pharyngeal depth (mm)	29.42	4.02	26.20	3.78	**< 0.0001**
The Need's Ratio (mm)	0.89	0.13	0.86	0.15	0.257
Angle of velum (mm)	129.13	4.89	130.23	6.39	0.308

*Obtained using Independent t-test; bold value indicated significance

Table 7f: Comparison of Morphological variations of soft palate (size)across groups

Morphological variations of soft palate	Group B (n=40)		Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Length of velum (mm)	33.11	3.99	32.38	4.34	30.38	4.01	30.00	5.53	30.13	5.49	**0.006**
Width of velum (mm)	8.94	2.42	8.59	1.94	8.78	1.56	8.54	1.91	8.38	2.12	0.760
Pharyngeal depth (mm)	29.42	4.02	27.96	4.16	26.75	3.55	25.64	2.97	24.46	3.57	**< 0.0001**
The Need's Ratio (mm)	0.89	0.13	0.86	0.10	0.89	0.16	0.87	0.17	0.83	0.15	0.240
Angle of velum (mm)	129.13	4.89	131.45	6.65	130.40	6.70	130.25	6.21	128.83	5.95	0.314

*Obtained using ANOVA; bold value indicated significance

Table 7g: Comparison of Morphological variations of soft palate (size) across OSMF patients

Morphological variations of soft palate	Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Length of velum (mm)	32.38	4.34	30.38	4.01	30.00	5.53	30.13	5.49	0.105
Width of velum (mm)	8.59	1.94	8.78	1.56	8.54	1.91	8.38	2.12	0.826
Pharyngeal depth (mm)	27.96	4.16	26.75	3.55	25.64	2.97	24.46	3.57	**< 0.0001**
The Need's Ratio (mm)	0.86	0.10	0.89	0.16	0.87	0.17	0.83	0.15	0.260
Angle of velum (mm)	131.45	6.65	130.40	6.70	130.25	6.21	128.83	5.95	0.334

*Obtained using ANOVA; bold value indicated significance

Table 8: Comparison of evaluation of tongue

Table 8a: Comparison of evaluation of tongue across three groups

Parameter Assessment	Group A (n=40)		Group B (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	Mean	SD	
Tongue length (mm)	73.79	4.08	76.16	5.41	74.12	5.72	0.079
Tongue height (mm)	30.14	2.86	29.22	2.15	31.67	25.49	**0.012**

*Obtained using ANOVA; bold value indicated statistical significance

Table 8b: Comparison of evaluation of tongue between Group A and B

Parameter Assessment	Group A (n=40)		Group B (n=40)		P-value*
	Mean	SD	Mean	SD	
Tongue length (mm)	73.79	4.08	76.16	5.41	**0.030**
Tongue height (mm)	30.14	2.86	29.22	2.15	0.107

*Obtained using Independent t-test; Bold value indicated significance

Table 8c: Comparison of evaluation of tongue between Group A and C

Parameter Assessment	Group A (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	
Tongue length (mm)	73.79	4.08	74.12	5.72	0.735
Tongue height (mm)	30.14	2.86	31.67	25.49	0.704

*Obtained using Independent t-test; Bold value indicated significance

Table 8d: Comparison of evaluation of tongue across groups

Parameter Assessment	Group A (n=40)		Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Tongue length (mm)	73.79	4.08	74.72	6.99	74.31	5.51	73.80	5.43	73.63	4.90	0.893
Tongue height (mm)	30.14	2.86	30.74	3.18	29.46	2.70	37.52	50.58	28.97	4.98	0.440

*Obtained using ANOVA; Bold value indicated significance

Table 8e: Comparison of evaluation of tongue between Group B and C

Paramete Assessment	Group B (n=40)		Group C (n=160)		P-value*
	Mean	SD	Mean	SD	
Tongue length (mm)	76.16	5.41	74.12	5.72	**0.043**
Tongue height (mm)	29.22	2.15	31.67	25.49	0.544

*Obtained using Independent t-test; Bold value indicated significance

Table 8f: Comparison of evaluation of tongue across all groups

Parameter Assessment	Group B		Group C1		Group C2		Group C3		Group C4		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Tongue length (mm)	76.16	5.41	74.72	6.99	74.31	5.51	73.80	5.43	73.63	4.90	0.288
Tongue height (mm)	29.22	2.15	30.74	3.18	29.46	2.70	37.52	50.58	28.97	4.98	0.409

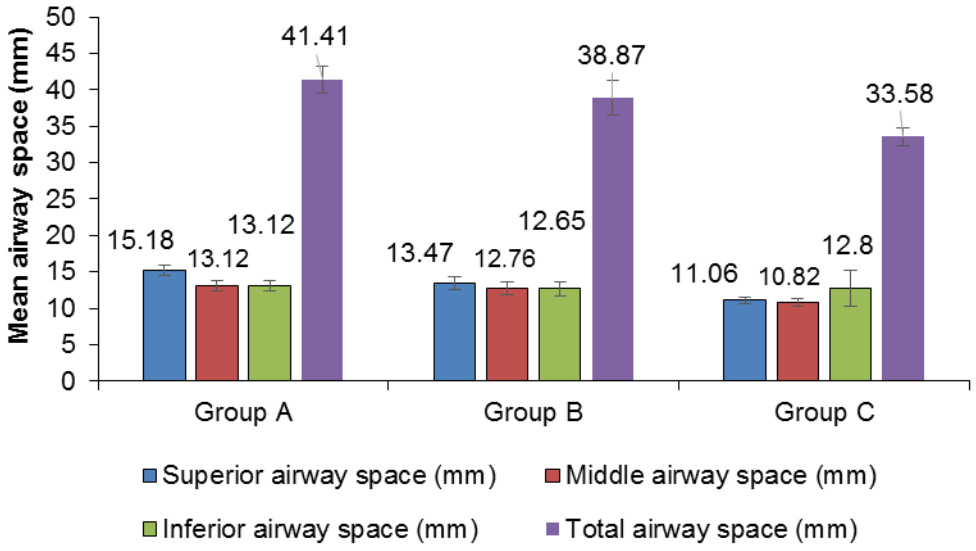
*Obtained using ANOVA; Bold value indicated significance

Table 8g: Comparison of evaluation of tongue across OSMF patients

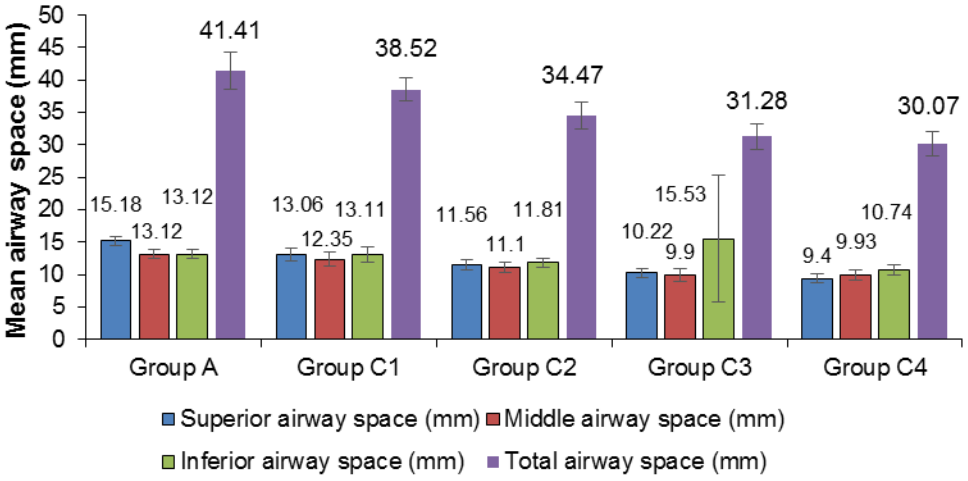
Parameter Assessment	Group C1 (n=40)		Group C2 (n=40)		Group C3 (n=40)		Group C4 (n=40)		P-value*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Tongue length (mm)	74.72	6.99	74.31	5.51	73.80	5.43	73.63	4.90	0.827
Tongue height (mm)	30.74	3.18	29.46	2.70	37.52	50.58	28.97	4.98	0.409

*Obtained using ANOVA; Bold value indicated significance

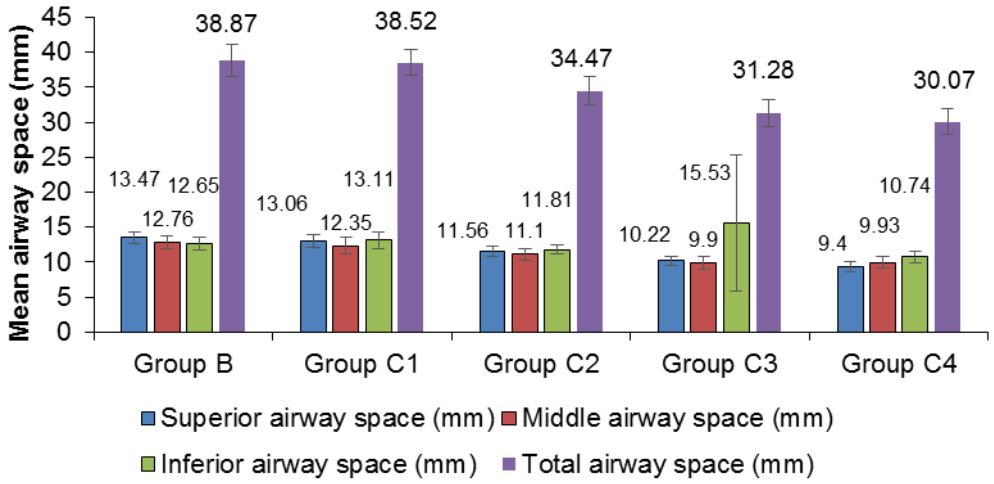
Graphs



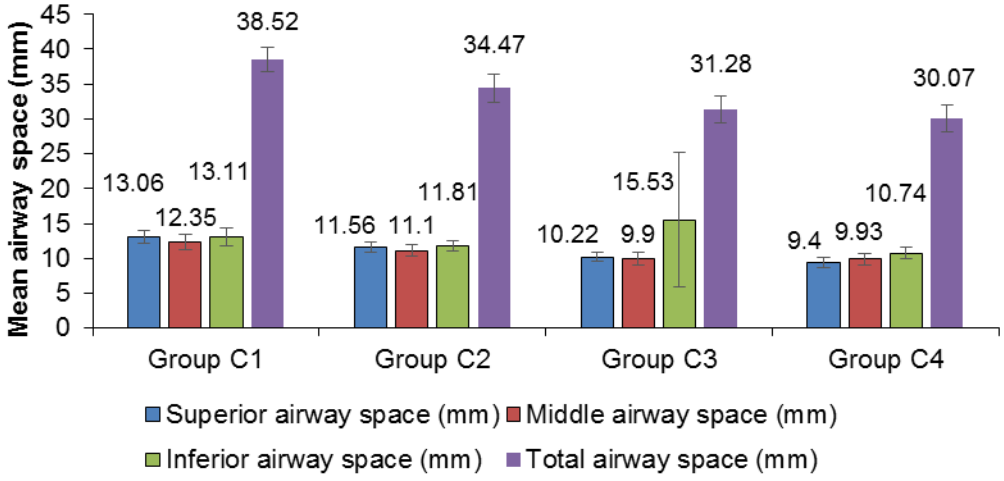
Graph 1: Column charts showing superior airway space, middle airway space, inferior airway space and total airway space in three groups



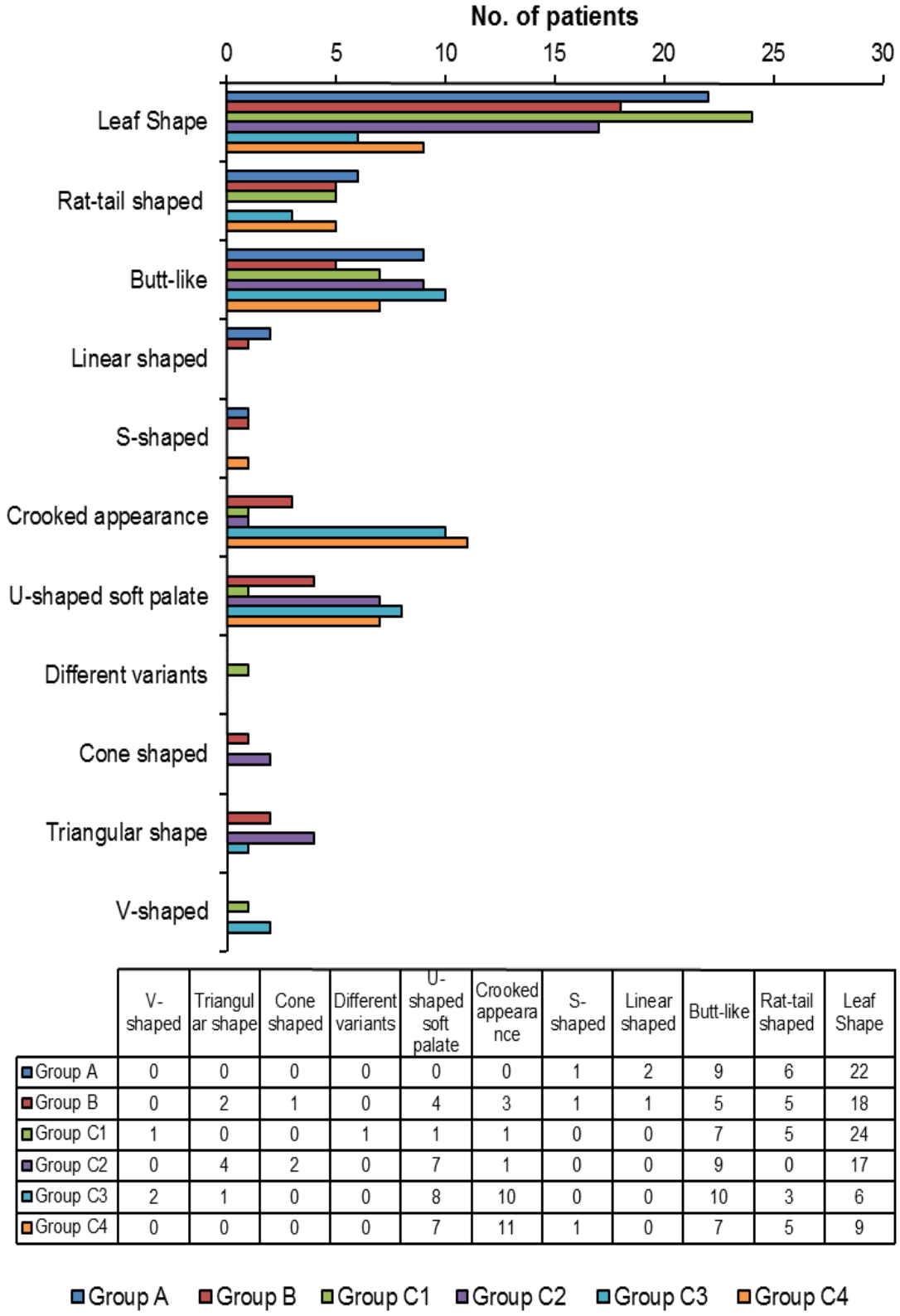
Graph 2: Column charts showing superior airway space, middle airway space, inferior airway space and total airway space between control and subgroups of OSMF



Graph 3: Column charts showing superior airway space, middle airway space, inferior airway space and total airway space between group B and subgroups of OSMF

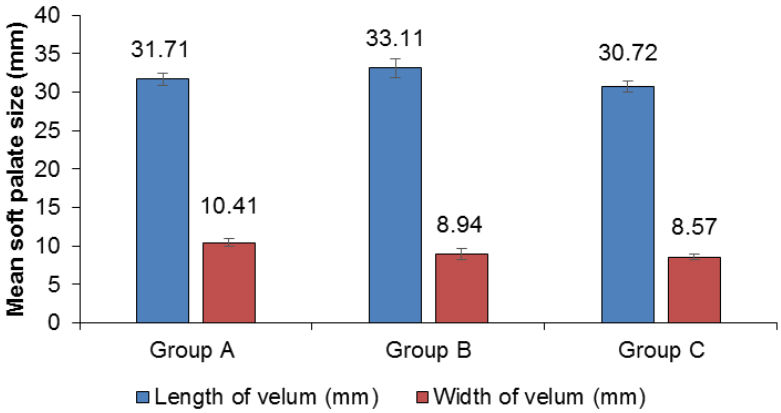


Graph 4: Column charts showing superior airway space, middle airway space, inferior airway space and total airway space between subgroups of OSMF

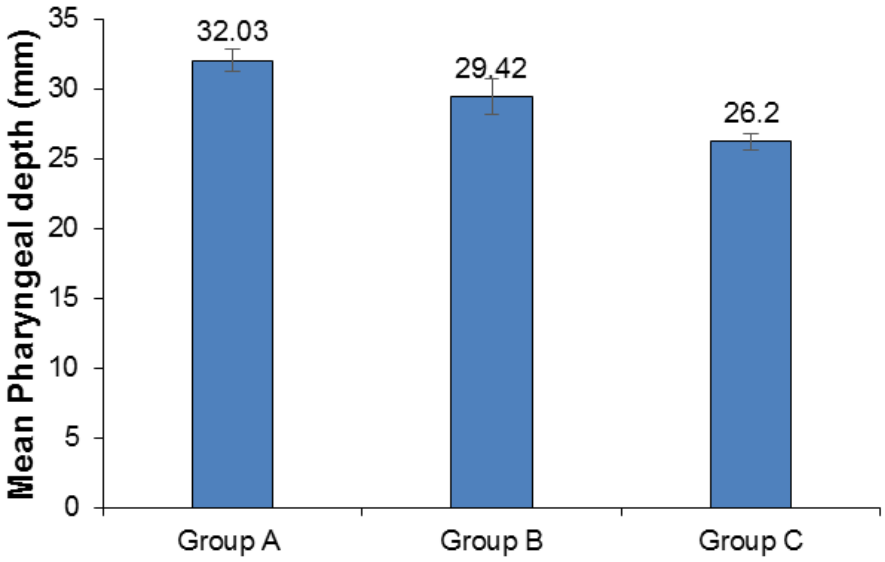


	V-shaped	Triangular shape	Cone shaped	Different variants	U-shaped soft palate	Crooked appearance	S-shaped	Linear shaped	Butt-like	Rat-tail shaped	Leaf Shape
Group A	0	0	0	0	0	0	1	2	9	6	22
Group B	0	2	1	0	4	3	1	1	5	5	18
Group C1	1	0	0	1	1	1	0	0	7	5	24
Group C2	0	4	2	0	7	1	0	0	9	0	17
Group C3	2	1	0	0	8	10	0	0	10	3	6
Group C4	0	0	0	0	7	11	1	0	7	5	9

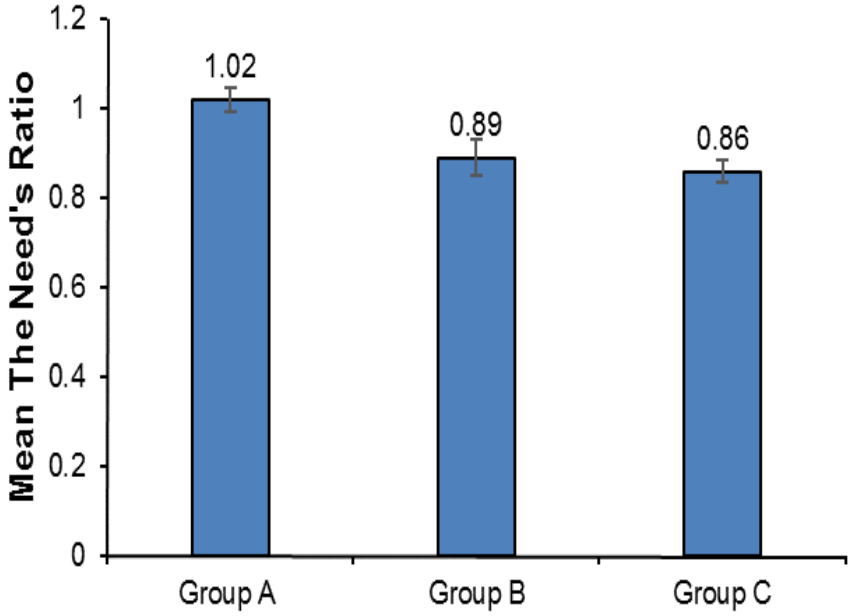
Graph5: Horizontal chart showing number of patients with different soft palate shapes



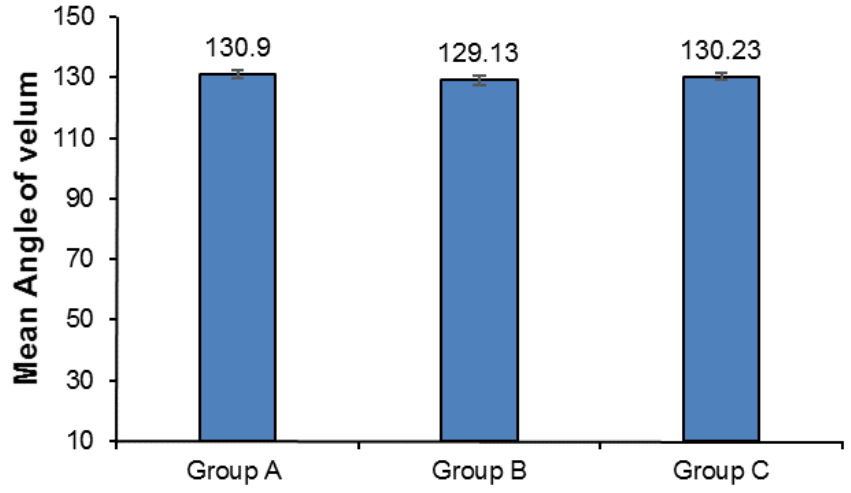
Graph 6a: Column charts showing length and width of soft palate in three groups



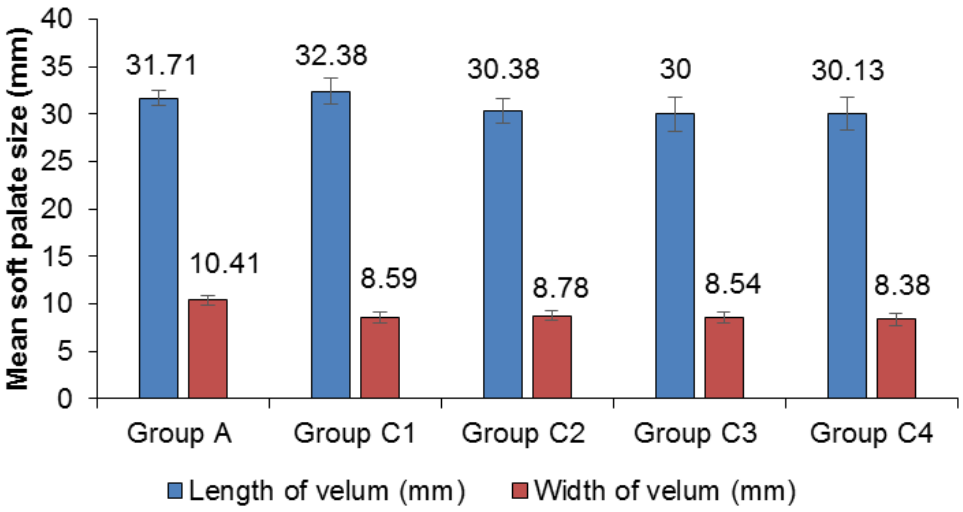
Graph 6b: Column charts showing pharyngeal depth of soft palate in three groups



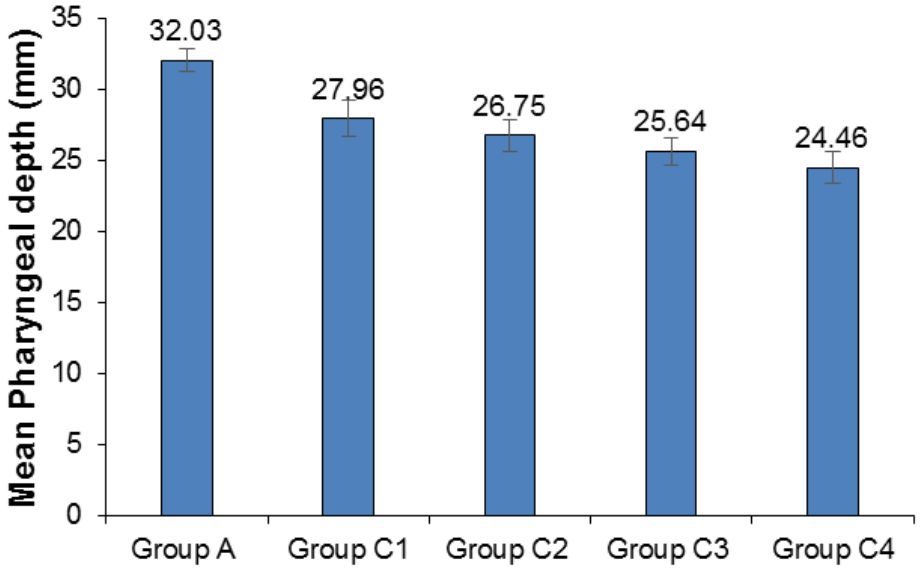
Graph 6c: Column charts showing need's ratio of soft palate in three groups



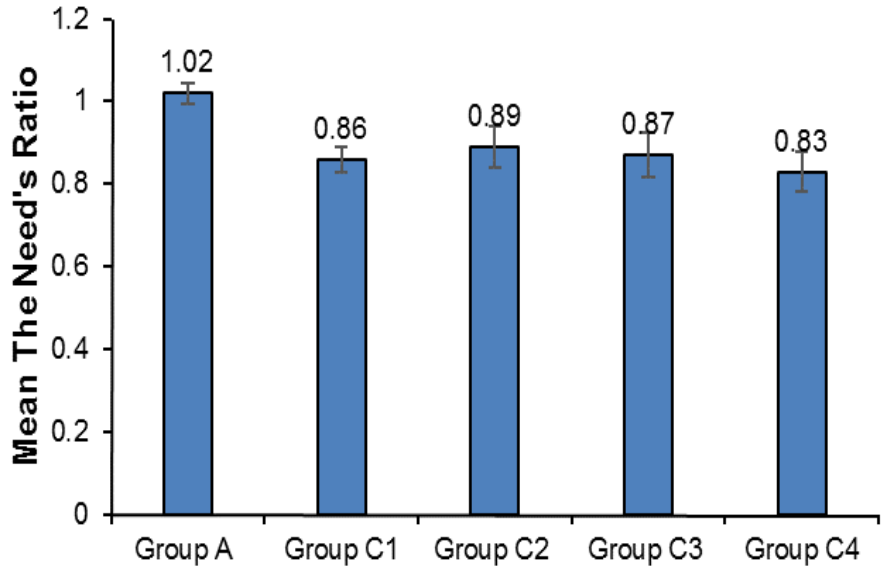
Graph 6d: Column charts showing angle of soft palate in three groups



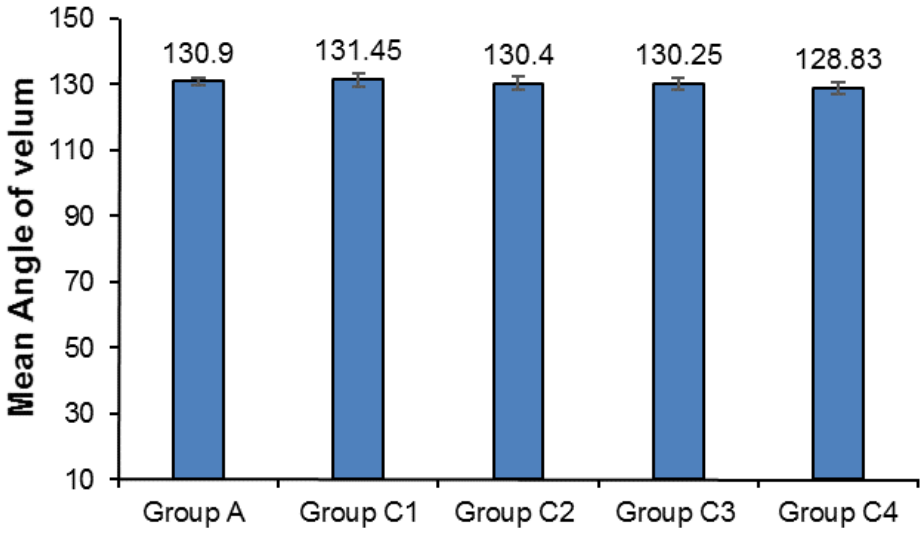
Graph 7a: Column charts showing length and width of soft palate between control and subgroups of OSMF.



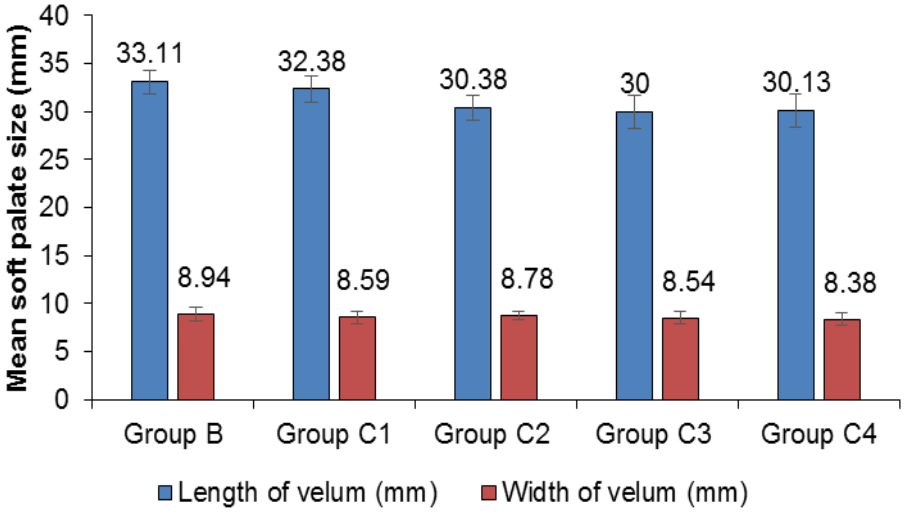
Graph 7b: Column charts showing pharyngeal depth of soft palate between control and subgroups of OSMF.



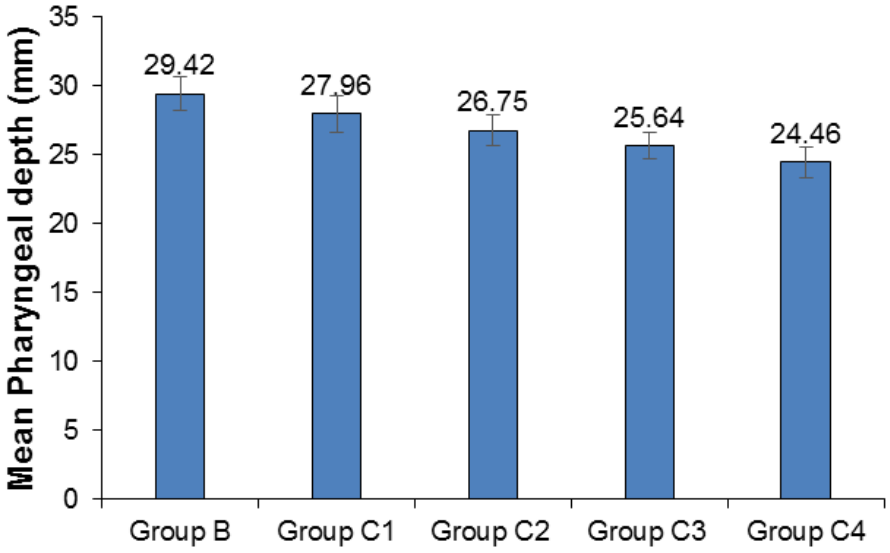
Graph 7c: Column charts showing need's ratio of soft palate between control and subgroups of OSMF.



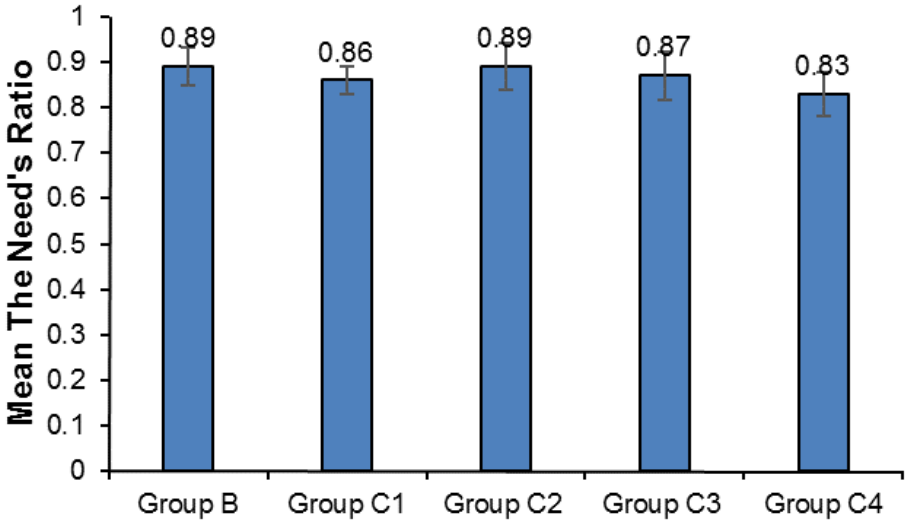
Graph 7d: Column charts showing angle of soft palate between control and subgroups of OSMF.



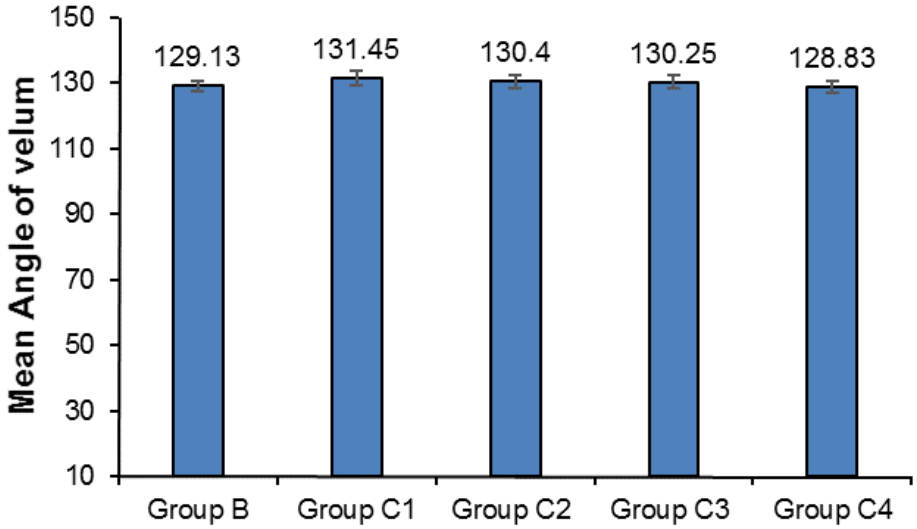
Graph 8a: Column charts showing length and width of soft palate between group B and subgroups of OSMF.



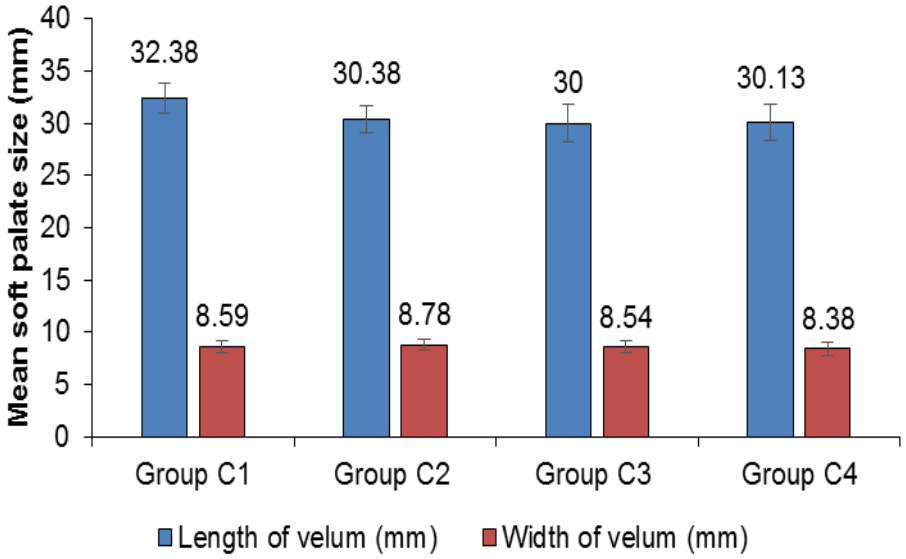
Graph 8b: Column charts showing pharyngeal depth of soft palate between group B and subgroups of OSMF.



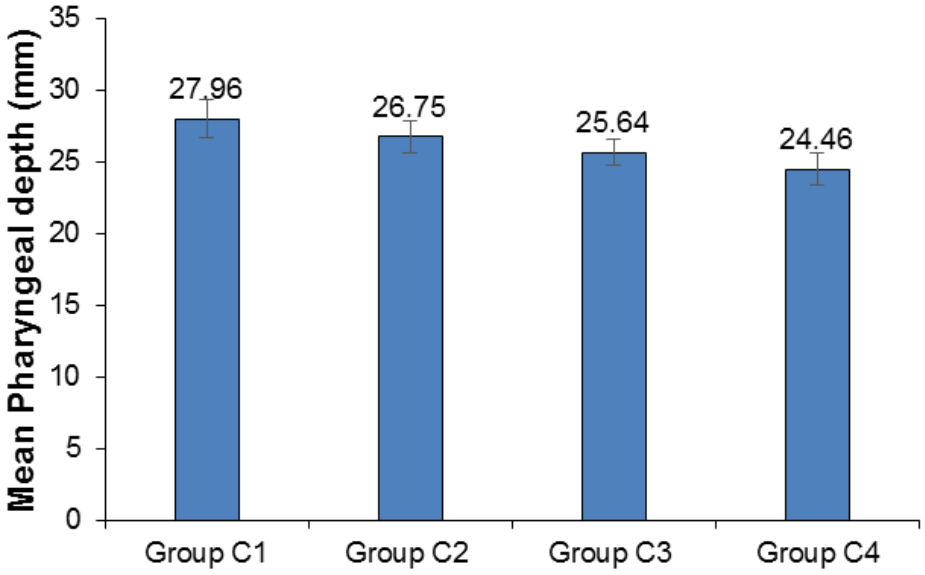
Graph 8c: Column charts showing need's ratio of soft palate between group B and subgroups of OSMF.



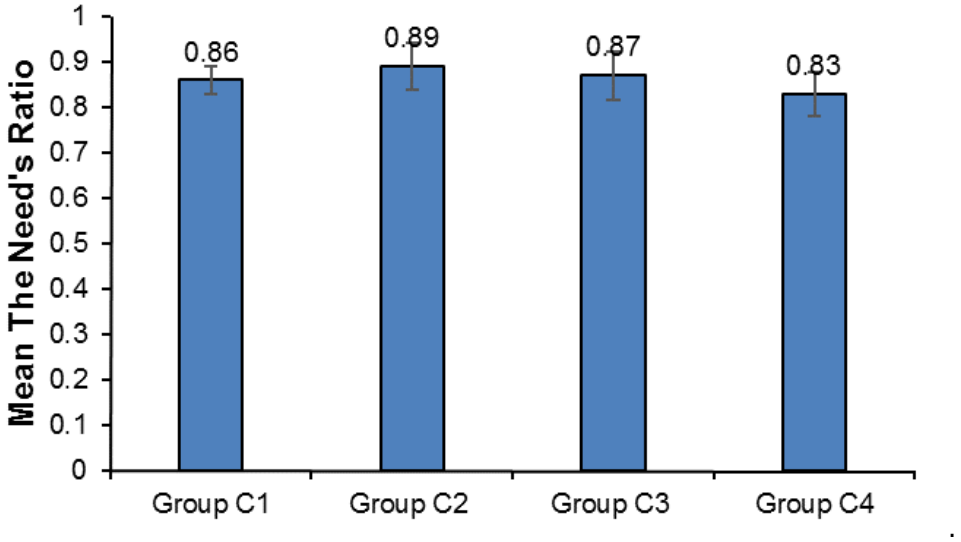
Graph 8d: Column charts showing angle of soft palate between group B and subgroups of OSMF.



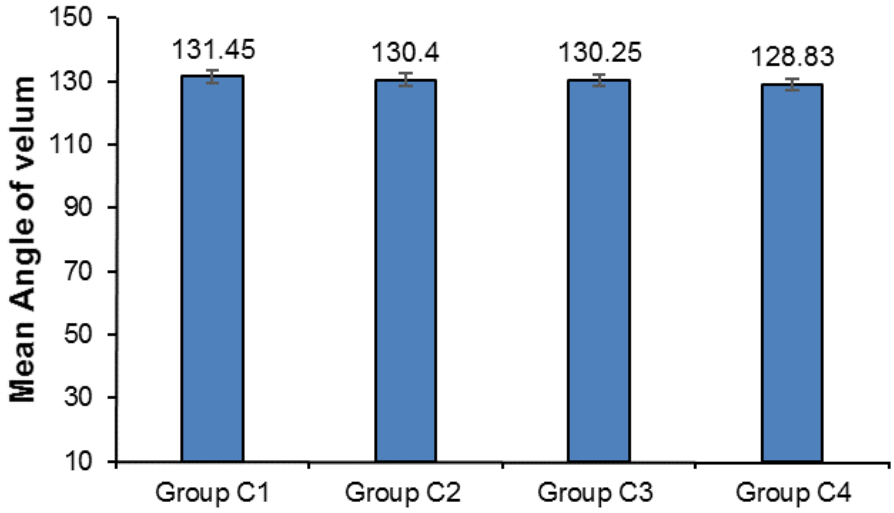
Graph 9a: Column charts showing length and width of soft palate between subgroups of OSMF.



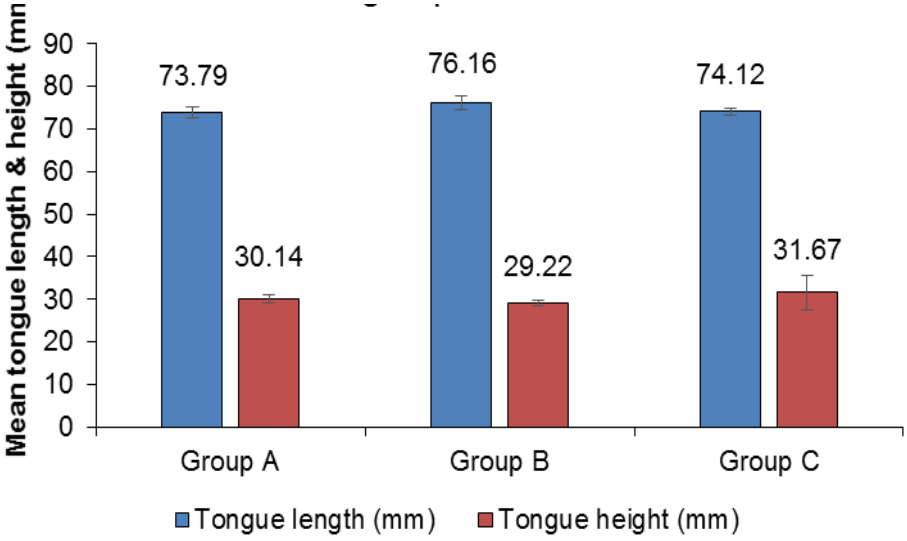
Graph 9b: Column charts showing pharyngeal depth of soft palate between subgroups of OSMF



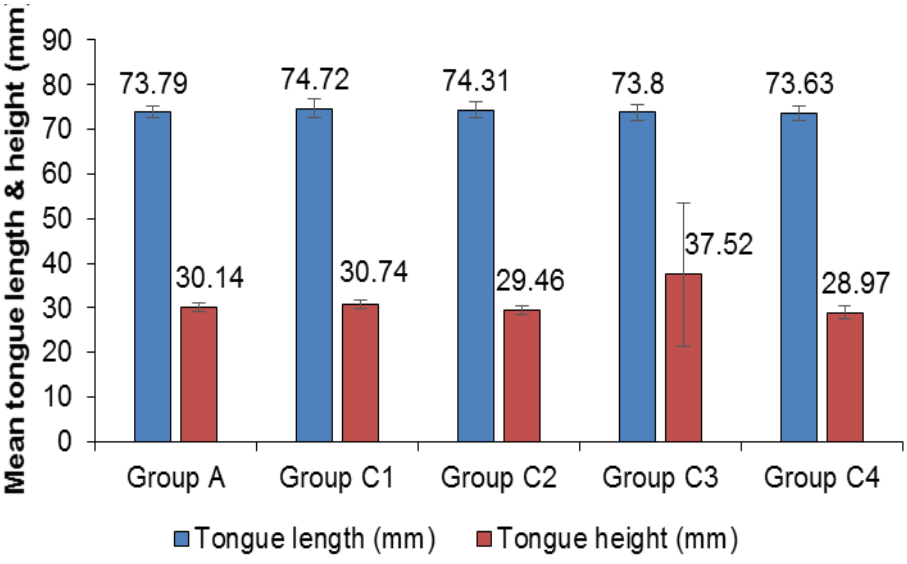
Graph 9c: Column charts need's ratio of soft palate between subgroups of OSMF.



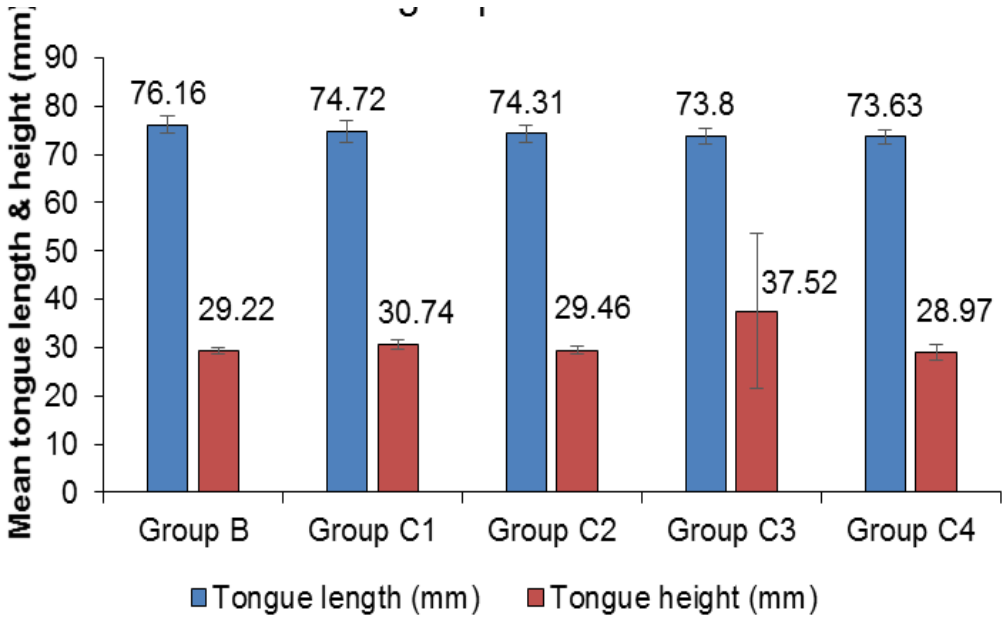
Graph 9d: Column charts showing angle of soft palate between subgroups of OSMF.



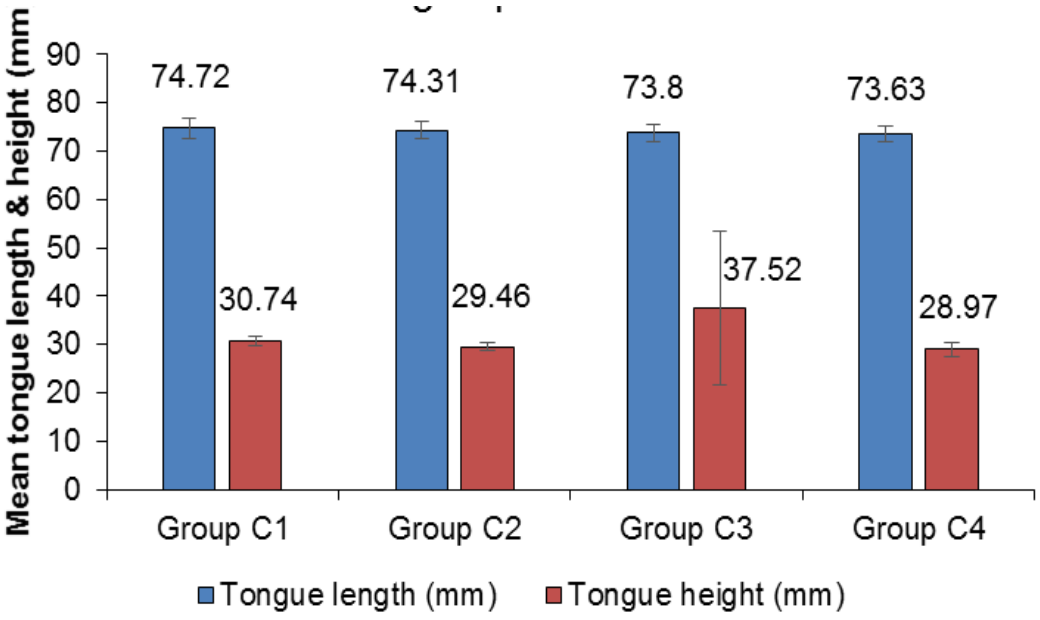
Graph 10: Column charts showing tongue length and tongue height in three groups



Graph 11: Column charts showing tongue length and tongue height between control and subgroups of OSMF

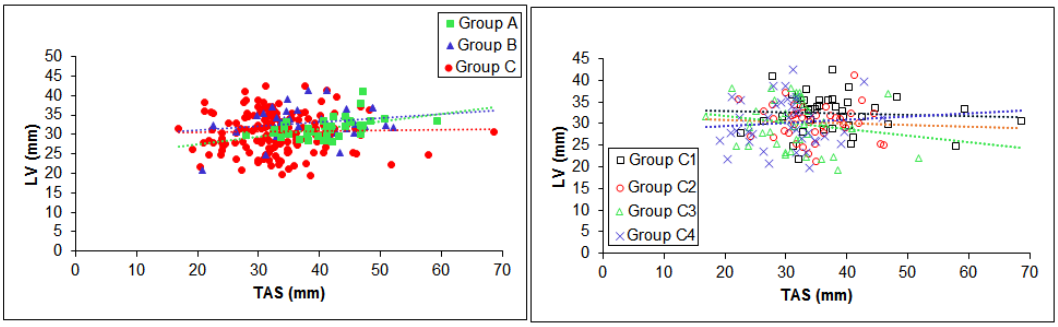


Graph 12: Column charts showing tongue length and tongue height between group B and subgroups of OSMF



Graph 13: Column charts showing tongue length and tongue height between subgroups of OSMF.

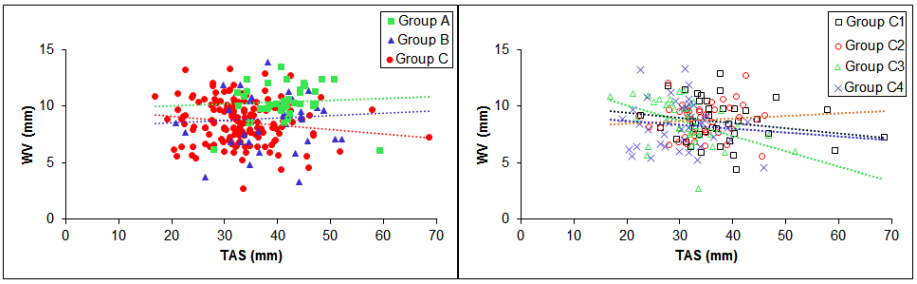
Scatter plots showing correlation analysis of total pharyngeal airway space and soft palate parameters in different groups and subgroups of OSMF.



Panel- A Panel- B

Group	Correlation	P-value
Group A	0.447	**0.004**
Group B	0.195	0.228
Group C	0.029	0.719
Group C1	-0.067	0.680
Group C2	-0.055	0.736
Group C3	-0.174	0.283
Group C4	0.081	0.619

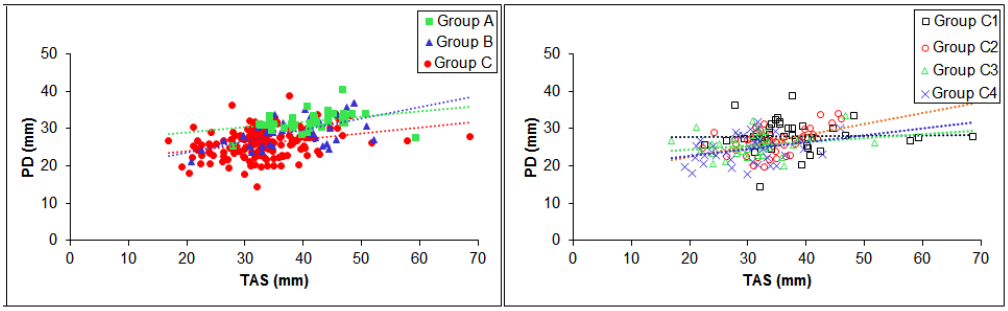
Graph 14: Correlation between total airway space and length of soft palate among groups. Panel A and B shows relationship in different groups and in subgroups of Group C (OSMF) respectively.



Panel- A Panel- B

Group	Correlation	P-value
Group A	0.062	0.706
Group B	0.064	0.696
Group C	-0.154	0.051
Group C1	-0.225	0.163
Group C2	0.086	0.597
Group C3	-0.452	**0.003**
Group C4	-0.100	0.540

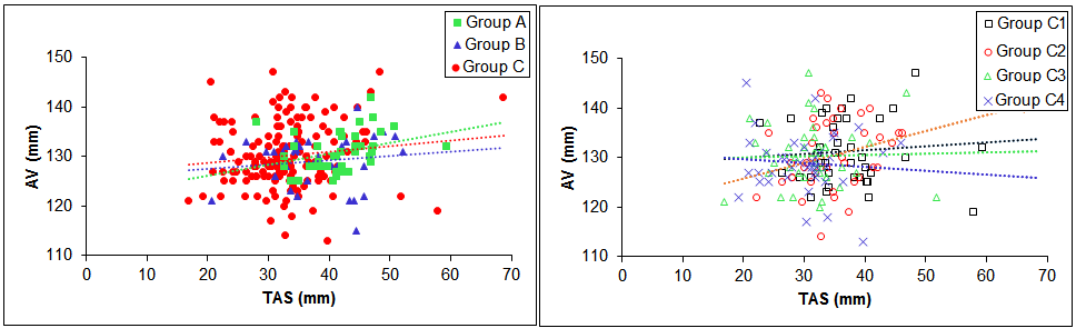
Graph 15: Correlation between total airway space and width of soft palate among groups. Panel A and B shows relationship in different groups and in subgroups of Group C (OSMF) respectively.



Panel- A Panel- B

Group	Correlation	P-value
Group A	0.325	**0.041**
Group B	0.556	**< 0.0001**
Group C	0.319	**< 0.0001**
Group C1	0.013	0.937
Group C2	0.467	**0.002**
Group C3	0.218	0.176
Group C4	0.315	**0.048**

Graph 16: Correlation between total airway space and pharyngeal depth among groups. Panel A and B shows relationship in different groups and in subgroups of Group C (OSMF) respectively.



Panel- A Panel- B

Group	Correlation	P-value
Group A	0.327	**0.040**
Group B	0.134	0.408
Group C	0.133	0.094
Group C1	0.112	0.492
Group C2	0.271	0.091
Group C3	0.026	0.874
Group C4	-0.079	0.626

Graph 17: Correlation between total airway space and angle of soft palate among groups. Panel A and B shows relationship in different groups and in subgroups of Group C (OSMF) respectively.

CASE HISTORY PROFORMA

Registration no. : Date:

Name : Age/Sex :

Address :

Religion : contact no.:

Education : Illiterate / Literate

Marital status : occupation:

Economic status : low/ moderate / high

Chief complaint:

History of present illness :

Medical history:

H/O major illness

H/O allergy

Current medical treatment if any -

Past dental history :

Family history

Personal history :

Diet: vegetarian / non vegetarian / mixed

Food habits :

Consumption of spicy food – occasional / regular / slight / moderate / severe

Green / red chillies – slight/ moderate/ severe

Addiction habits:

Habits Particular	Frequency Per day	quantity per day	since	location if any
Chewing of				
Areca nut				
Kharra				
Tobacco				
Tobacco + lime				
Others				
Smoking of				
Bidi				
Cigarette				
Chutta				
Hukka				
Alcohol				

Oral hygiene habits:

Cleaning teeth with: tobacco / toothpaste/ coal/ snuff / powder / salt/ ash/other

With tooth brush / finger / datoon

Sleep cycle:

Menstrual cycle:

Bowel and bladder movements :

Parafunctional habits

General examination

Built :

Gait :

Height :

Weight :

Temperature :

Pulse :

Respiratory rate :

Blood pressure :

Pallor :

Icterus :

Cyanosis :

Clubbing :

Odema :

Generalized lymphadenopathy :

Extraoral examination

Facial symmetry

Eyes

Ears

Nose

Head

Neck

Skin

TMJ

Lymph node

Intraoral examination

Hard tissue examination

Teeth present

Occlusion

Attrition

Erosion

Abrasion

Caries

Tenderness

Root pieces

Furcation involvement

Fracture

Restored teeth

Stains/ calculus

Healed/ unhealed socket

Prosthesis

Soft tissue examination

Buccal mucosa

Labial mucosa

Palate (hard/ soft)

Uvula

Faucial pillars

Retromolar area

Tongue

Floor of mouth

Vestibule

Gingiva

Other features:

Function of -

Tongue

Cheeks

Speech defect -

Difficulty in swallowing -

Burning sensation in oral cavity -

Local examination for OSMF

Interincisal distance _____ mm

Examination of mucosa:

Blanching

Pigmentations – increased / decreased

Erythematous areas

Ulcerations

Fibrous bands- single/ multiple/ broad / circumoral / vertical / unilateral / bilateral

Uvula – normal/ atropic

Tongue protrusion – normal/ incisal tip / upto lower lip / beyond mucocutaneous junction

Provisional diagnosis:

Investigations :

RADIOGRAPHICAL ANALYSIS:-

I. Morphology of soft palate (shape)-

Type 1 ☐ Type 2 ☐ Type 3 ☐ Type 4 ☐

Type 5 ☐ Type 6 ☐ Type 7 ☐ Type 8 ☐

Type 9 ☐ Type 10 ☐ Type 11 ☐

II. Evaluation of pharyngeal airway space -

1. Superior airway space (SAS) ___
2. Middle airway space (MAS) ___
3. Inferior airway space (IAS) ___
4. Tongue length (TGL) ___
5. Tongue height (TGH) ___

III. Measurements of soft palate (size):

1. Length of Velum [LV] ___
2. Width of Velum [WV] ___
3. Pharyngeal Depth [PD] ___
4. The Need's Ratio [NR] ___
5. Angle of Velum [AV] ___

(Confidential)

Informed Consent Form

.Evaluation of Pharyngeal Airway Space and Soft Palate in Oral Submucous Fibrosis Patients- A Digital Lateral Cephalogram Study

Patients I.D.:

I,
Mr./Master/Mrs./Miss._____
__

Resident of: _____

_____

_____ aged _____ years, exercising my free will/choice, without any pressure/lure of incentive in any form, hereby give my consent/consent on behalf of patient named

Mr./Master/Mrs./Miss._____

Resident of: _____aged _____ years,

as his/her _____.

I acknowledge that doctor has informed me about this research project suitably and sufficiently to my satisfaction. I agree to let my X-rays, photographs, impressions and other investigations to be taken as required. I agree to take part in this project and will not mix any other projects during the period of this trial. I shall report to the dental hospital or other place where called on given appointment dates and time. I shall inform the doctor on any adverse effects or unusual symptoms noticed by me. I shall co-operate with the doctors and paramedical staff, in all respects. I permit to publishing the results of my participation in this study. I shall not be given any reimbursement or compensation. I have been informed of my right to opt out of this research project at any time without giving any reason for doing so.

I hereby record my consent for participation in the said trial.

1.	_____	_____	_____	_____
	Patient's name	Signature/thumbprint	Date	Time
Or	_____	_____	_____	_____
	Person providing consent	Signature/thumbprint	Date	Time
2.	_____	_____	_____	_____
	Witness name	Signature	Date	Time
3.	_____	_____	_____	_____
	Investigator's name	Signature	Date	Time

(Confidential)

Informed Consent Form

Evaluation of Pharyngeal Airway Space and Soft Palate in Oral Submucous Fibrosis Patients- A Digital Lateral Cephalogram Study

वैयक्तीक माहिती

रूग्णाचे नाव : दिनांक :
वय/लिंग :
पत्ता :

मोबाईल नंबर :

मी कबूल करतो की डॉक्टरांनी मला या संशोधन प्रकल्पाबद्दल समाधानकारक माहिती दिली आहे. मी माझ्या एक्स-रे, छायाचित्रे, इंप्रेशन आणि आवश्यकतेनुसार अन्य तपासण्या करण्यास सहमत आहे. मी या प्रकल्पात भाग घेण्यास सहमती देतो आणि या चाचणीच्या कालावधीत कोणतेही अन्य प्रकल्प एकत्रित करणार नाही. मला डेन्टल हॉस्पिटल किंवा इतर ठिकाणी दिलेल्या भेटीची तारीख आणि वेळ सांगितली आहे. मी डॉक्टर आणि पॅरामेडिकल कर्मचा-यांना सर्व बाबतीत सहकार्य करेल. या अभ्यासात मी माझ्या सहभागाचे निकाल प्रकाशित करण्यास परवानगी देतो. मला कोणतीही नुकसान भरपाई दिली जाणार नाही. असे करण्यासाठी कोणतेही कारण न देता मला कोणत्याही वेळी या संशोधन प्रकल्पातून बाहेर पडण्याचा अधिकार मिळालेला आहे. मी या अन्वये केलेल्या चाचणीत सहभागासाठी माझी संमती नोंदवित आहे.

१) रूग्णाचे नाव	स्वाक्षरी	तारीख	वेळ
२) साक्षीदाराचे नाव	स्वाक्षरी	तारीख	वेळ
३) डॉक्टरचे नाव	स्वाक्षरी	तारीख	वेळ

(Confidential)

Informed Consent Form

Evaluation of Pharyngeal Airway Space and Soft Palate in Oral Submucous Fibrosis Patients- A Digital Lateral Cephalogram Study

वैयक्तीक जानकारी

मरीज का नाम : तारीख :

उम्र/लिंग :

पत्ता :

मोबाईल नंबर :

मैं मानता हूं कि चिकित्सक ने मुझे इस शोध परियोजना के बारे में उपयुक्त और पर्याप्त रूप से मेरी संतुष्टि के बारे में बताया है। मैं अपने एक्स-रे, फोटो, इंप्रेशन और अन्य जांचों को जरूरी के रूप में लेने के लिए सहमत हूं। मैं इस परियोजना में भाग लेने के लिए सहमत हूं और इस परीक्षण की अवधिके दौरान किसी भी अन्य परियोजनाओंको मिला नहीं करेगा। मैं सभी मामलों में डॉक्टरों और पैरामेडिकल स्टाफ के साथ मिलकर काम करूगा। मैं इस अध्ययन में अपनी भागीदारी के परिणामोंको प्रकाशित करने की अनुमति देता हूं। मुझे कोई प्रतिपूर्ति या क्षतिपूर्ति नहीं दी जाएगी। मुझे ऐसा करने के लिए किसी भी कारण के बिना किसी भी समय इस शोधपरियोजनासे ऑप्टआउट करने का मेरे अधिकार के बारे में सूचित किया गया है। मैं एतद्वारा परीक्षण में भाग लेने के लिए मेरी सहमति रिकॉर्ड करता हूं।

१) मरीज का नाम	सही	तारीख	समय
२) साक्षीदार का नाम	सही	तारीख	समय
३) डॉक्टर का नाम	सही	तारीख	समय

MASTER CHART

Sr. No.	Age/ Sex	Habit	Group	Airway Assessment in mm					Shape of Soft Palate	Soft Palate Assessment in mm				
				SAS	MAS	IAS	TGL	THG		LV	WV	PD	NR	AV
1	24/ M	kharra	GROUP 1	17	12.1	15.6	79	31.1	Type 1	33.7	8.9	30	0.89	140
2	42/M	kharra	GROUP 1	12.5	12.5	14.2	78.6	37	Type 1	33	8.4	20.4	0.61	126
3	40/F	areca nut	GROUP 1	16	11.5	10.2	61.5	27.1	Type 1/7	28.9	6.4	28	0.96	129
4	39/M	kharra	GROUP 1	12.4	10.2	10.4	78	32.2	Type 1	35.3	8.5	27.7	0.78	139
5	34/M	kharra	GROUP 1	13.2	12.3	12.7	74.2	32.4	type 1	34	9.8	26.9	0.79	126
6	55/M	kharra+tobacco	GROUP 1	12.9	13.9	13.6	82.1	35.2	type 1	38.4	9.8	27.7	0.72	125
7	50/M	kharra+ tobacco & lime	GROUP 1	13.8	11	12.8	83.7	36.6	Type 1	42.5	12.9	38.9	0.91	142
8	37/m	kharra	GROUP 1	15.3	12.6	12.7	69.4	35.5	type 2	25.4	4.4	22.9	0.9	122
9	32/m	kharra	GROUP 1	21.4	18.7	19.2	81.3	34.5	type 1	33.5	6.1	27.6	0.82	132
10	45/F	kharra+ areca nut	GROUP 1	15.3	8.8	9.5	68.3	26.6	type 1	33.2	7.5	29	0.87	123
11	44/F	areca nut	GROUP 1	11	13.1	10.7	68.3	28.1	type 3	33.3	7.8	32.3	0.96	136
12	27/M	kharra	GROUP 1	12.2	18	16.5	79.6	28	type 1	29.9	7.6	28.2	0.94	130
13	21/M	kharra	GROUP 1	19.3	23.6	25.7	82.2	29.2	type 11	30.7	7.3	27.9	0.9	142
14	43/M	kharra+ tobacco & lime	GROUP 1	12	11.5	13.5	81.4	36.6	type 7	35.3	8	30.2	0.85	138
15	34/M	kharra	GROUP 1	10.6	11.7	11.3	90.4	31.6	type 3	32.4	10.5	30.1	0.92	140
16	32/M	kharra	GROUP 1	21.4	18.7	19.2	81.3	34.5	type 1	33.5	6.1	27.6	0.82	132
17	38/M	kharra	GROUP 1	13.1	17.9	17.2	80.9	28.6	1	36.3	10.8	33.4	0.92	147
18	41/F	areca nut	GROUP 1	11.1	11	10.7	66.6	27.6	3	28	8	26.6	0.95	129
19	40/M	kharra+ tobacco & lime	GROUP 1	11.5	9.7	12.2	79.5	25.7	1	38	11.1	26.7	0.7	129
20	50/M	kharra+ tobacco	GROUP 1	13.4	8.7	10	66	26.9	8	21.9	6.4	14.3	0.65	131
21	24/M	kharra	GROUP 1	13.3	11.2	11	76	26.3	1	34.1	9.2	31.9	0.93	133
22	40/F	areca nut	GROUP 1	10.9	6.7	8.7	71	26.7	6	30.5	8.1	26.7	0.87	127
23	31/M	kharra	GROUP 1	12.3	13	14.2	79.9	31.2	2	31.6	6.9	30.6	0.96	130
24	28/M	kharra	GROUP 1	13.6	9.8	11.8	76.9	31	1	34	10.5	32.9	0.96	131

25	30/M	kharra	GROUP 1	11.1	7.4	9.3	73.4	30	1	41	11.8	36.2	0.88	138

26	28/F	areca nut	GROUP 1	12.4	10.6	9.5	70.3	29.1	1	34.4	8.7	26.4	0.76	132
27	42/F	areca nut	GROUP 1	11.8	8.4	9.1	64	31.3	2	31.6	7.1	27.3	0.86	126
28	45/M	kharra	GROUP 1	10.9	13.1	11.4	71.6	30.4	1	35.3	9.8	31.2	0.88	138
29	27/M	kharra	GROUP 1	11.3	15.6	15.6	65.7	31.5	3	31.6	9.6	23.9	0.75	138
30	30/M	kharra	GROUP 1	11.8	13	15.5	65.9	27.7	1	29.7	7.6	24.9	0.83	125
31	25/M	kharra	GROUP 1	11.5	14.6	14	76	32.4	2	34.8	5.7	25.2	0.72	128
32	60/M	kharra+ tobacco & lime	GROUP 1	8.2	11.2	11.6	72.3	31.4	1	36.8	11.5	27.9	0.75	122
33	28/M	kharra	GROUP 1	12.6	9.2	12.2	89.1	29.7	2	30.8	5.9	24.4	0.79	127
34	35/M	kharra	GROUP 1	10.9	12.2	13.1	67.9	31.6	3	28.6	8.1	27.9	1.07	140
35	27/M	kharra	GROUP 1	15.2	18.3	24.3	70.9	29.2	3	24.8	9.7	26.7	1.07	119
36	38/M	kharra	GROUP 1	10.6	9.8	13.7	73.4	30.1	1	33.3	11	31.1	0.93	124
37	28/M	kharra	GROUP 1	13	12.7	11.9	73.8	32.1	1	35.6	11.4	30.1	0.84	132
38	30/M	kharra	GROUP 1	8.2	7.5	6.9	73.9	31.7	1	27.8	9.2	25.5	0.91	137
39	21/M	kharra	GROUP 1	12.7	14.6	13.7	80.6	35.5	3	26.8	8.7	27.5	1.02	127
40	30/F	areca nut	GROUP 1	14.7	7.5	8.9	64	25.7	1	24.8	6.8	23.7	0.95	126

group C2														
1	44/M	kharra+ areca nut	GROUP 2	14.4	12.8	14.1	78.5	25.8	Type 6	41.2	9	28.5	0.69	128
2	36/M	kharra	GROUP 2	14	7.7	11	81.5	32.1	Type 1	31.4	7.7	28	0.89	128
3	21/M	kharra	GROUP 2	16.9	11.1	10.9	74.3	30.9	Type 1	31.2	6.6	26.8	0.85	126
4	18/M	kharra	GROUP 2	11.4	9.5	10.4	69.6	29.7	Type 1	34.3	9.7	28.6	0.83	133
5	34/M	kharra	GROUP 2	10.3	9.3	10.1	68.8	32.2	Type 1	28.3	6.8	22.5	0.79	121
6	60/M	kharra+ tobacco & lime	GROUP 2	12.4	13.1	13.9	72.1	27.3	type 1	29.8	9.9	27.8	0.93	139
7	29/M	kharra	GROUP 2	14.7	10.1	11.8	74.1	33.1	type 1	33.8	9.7	22.5	0.66	129
8	20/M	kharra	GROUP 2	11.1	13.2	11.9	76	29.8	type 3	27.8	8.6	25.5	0.91	130
9	54/M	kharra+ areca nut	GROUP 2	12.4	15.8	14.2	88.1	29.7	type 10	35.3	12.7	33.8	0.95	134

10	18/M	kharra	GROUP 2	12.9	9.5	10.4	71.5	28.8	type 7	33.9	6.8	31.1	0.91	143
11	37/M	kharra	GROUP 2	11.6	10	9.7	74.1	27.2	type 3	32.1	9.4	30.4	0.94	130
12	32/M	kharra	GROUP 2	14.5	15.8	14.1	74.3	34.8	type 7	32.4	8.9	31.4	0.96	133

13	29/M	kharra	GROUP 2	11.7	7.8	8.5	68.2	29	1	26.8	9.7	24.2	0.9	126
14	27/M	kharra	GROUP 2	10.6	6.6	9.2	76.7	27.7	9	32.8	8.1	22.4	0.68	125
15	44/M	kharra+ tobacco & lime	GROUP 2	8.2	6.1	7.9	73.6	28.2	1	35.7	9.1	24.8	0.69	122
16	17/M	kharra	GROUP 2	12.5	9.4	10.9	69.3	28.2	3	24.6	7.4	19.8	0.8	114
17	26/F	areca nut	GROUP 2	12	11.8	10.9	64	26.9	7	28.2	6.5	24	0.85	123
18	33/M	kharra	GROUP 2	15.3	8.9	13.1	74.3	30	9	31.9	7.7	22.8	0.71	119
19	38/M	kharra	GROUP 2	11.5	14.9	13.4	84	27.1	3	29.2	8	29.7	1	135
20	52/F	areca nut	GROUP 2	8.1	7.4	8.7	72.4	29	3	27	8.2	28.9	1.07	135
21	28/M	kharra	GROUP 2	10.7	9.6	10.1	68	29.1	1	27.8	10.1	27.4	0.98	129
22	30/M	kharra	GROUP 2	12.4	9.8	11.5	75.3	28.5	1	31.8	9.5	26.8	0.84	137
23	31/M	kharra	GROUP 2	15.5	15.2	15.3	72	33.4	3	25.1	9.2	32.6	1.29	135
24	38/M	kharra	GROUP 2	10	9	11	83.6	32	7	37.1	9.5	27	0.72	128
25	53/M	kharra+ tobacco & lime	GROUP 2	8.8	16.7	16.5	73.6	28.7	3	30.1	10.1	27.4	0.91	128
26	30/M	kharra	GROUP 2	8.8	13.3	13.9	72.3	26.2	1	29.7	10.4	27.7	0.93	140
27	43/F	areca nut	GROUP 2	10.8	10.9	12.1	78.8	27.7	1	30.3	9	28.2	0.93	142
28	28/F	areca nut	GROUP 2	9.6	7.9	10.4	63.8	26.6	7	31.2	6.6	25.9	0.83	126
29	38/M	kharra	GROUP 2	10.2	9.1	8.4	74.1	26	1	34.3	12.1	27.1	0.79	129
30	23/M	kharra	GROUP 2	19.1	13.5	13	85	29	7	25.3	5.6	33.9	1.33	135
31	43/M	kharra+ tobacco & lime	GROUP 2	9.3	11.3	11.4	79.1	32.2	1	32.3	8.9	29.4	0.91	136
32	31/F	areca nut	GROUP 2	12.1	8.7	10.6	65.1	24.3	7	29.8	6.7	28.6	0.95	138
33	39/M	kharra	GROUP 2	9.5	11.3	14.2	68.7	29.6	10	31.8	7.7	21.9	0.68	122
34	21/M	kharra	GROUP 2	10	12.5	11.1	76.3	36.7	3	23	9.7	21.7	0.94	128
35	17/M	kharra	GROUP 2	8.8	11.6	11.4	78.6	33.6	3	25.4	9.5	22.2	0.87	127
36	51/M	kharra	GROUP 2	9.7	14.1	16.9	70.2	27.7	1	32.4	10.9	30.1	0.92	140
37	23/M	kharra	GROUP 2	9.4	13.2	15.6	74.6	31.9	10	31.5	10.6	25.9	0.82	125

38	28/M	kharra	GROUP 2	11.4	11.7	11.7	78.1	32.1	1	25.3	7.9	26.5	1.04	138
39	63/F	kharra+ tobacco & lime	GROUP 2	9.7	13	12.2	72.8	27.8	1	21.2	9.3	26.3	1.24	135
40	20/M	kharra	GROUP 2	10.1	10.8	10.1	76.9	27.9	10	31.9	7.3	20	0.62	125

GROUP C3														
1	34/M	kharra	GROUP 3	8.4	8.9	8.9	71.5	32.1	1	27.8	10.6	21.2	0.76	122
2	43/M	kharra	GROUP 3	6.6	11.3	14.7	80.3	34.3	Type 6	36.1	10.4	22.8	0.63	120
3	47/M	kharra+ tobacco & lime	GROUP 3	11	12	10.4	69.9	28.5	3	22.2	7.8	26.4	1.18	132
4	37/M	kharra	GROUP 3	8.2	8.4	8.4	72.4	25.3	Type 6	32.8	10.4	26	0.79	129
5	43/M	kharra	GROUP 3	13.1	10.6	9.2	68.6	31.9	7	29.9	8.3	29.3	0.97	121
6	55/M	kharra+ areca nut	GROUP 3	6.1	10.3	11.7	78.2	34.6	Type 6	35.3	10.6	23.4	0.66	122
7	41/M	kharra	GROUP 3	10.6	8.7	11.5	81.7	27	Type 7	38.2	11.4	32	0.83	141
8	23/M	kharra	GROUP 3	10.9	8.3	12.5	68.3	26.6	Type 6	26.4	8	22.8	0.86	131
9	35/F	areca nut+ tobacco	GROUP 3	10.2	9.6	11	70.6	26.6	3	23.6	9.8	28.2	1.19	147
10	23/M	kharra	GROUP 3	11.8	11.7	12.7	76.3	31	7	30.4	6.4	20.1	0.66	128
11	42/M	kharra+ tobacco & lime	GROUP 3	8.1	14.8	14.9	73.1	29	3	22.4	9.6	25.6	1.14	134
12	43/F	areca nut	GROUP 3	12	10.9	9.3	71.6	31.7	Type 7	37.1	7.7	26.1	0.7	128
13	31/M	kharra	GROUP 3	11.6	10	10.3	67	28.9	Type 7	35.3	7.5	28.8	0.81	129
14	40/M	kharra	GROUP 3	14	17.9	19.9	77.4	28.2	11	22.1	6	26.2	1.18	122
15	23/M	kharra	GROUP 3	11.6	12.2	12.1	69.5	30.5	type 3	21.9	7.5	22.1	1	124
16	32/M	kharra	GROUP 3	11.7	8.6	13.4	72.3	33.1	Type 6	32.9	7.4	24.7	0.75	126
17	35/M	kharra	GROUP 3	8.4	5.9	9.8	73.4	27.9	1	29	6.4	20.5	0.7	127
18	54/M	kharra+ tobacco & lime	GROUP 3	8.8	10.6	8.2	83.4	30.2	7	38.2	8.8	26.9	0.7	128
19	27/M	kharra	GROUP 3	8.6	6.2	9.2	83	30	1	30.4	11	23.3	0.76	137
20	46/M	kharra+ tobacco & lime	GROUP 3	6.5	5.2	5.2	69	31.1	3	31.6	10.9	26.6	0.84	121

21	32/M	kharra	GROUP 3	11.7	8.6	13.4	72.3	33.1	6	32.9	7.4	24.7	0.75	126
22	30/M	kharra	GROUP 3	12.2	10.2	10.1	85.6	31.9	7	36.3	9	26.9	0.74	127
23	24/M	kharra	GROUP 3	10.4	9.5	8.6	75.9	27.3	1	25.4	10.3	25.4	1	130
24	35/M	kharra	GROUP 3	13.9	11.7	12.9	71.8	26.5	3	19.3	5.9	26.8	1.38	127
25	22/F	areca nut	GROUP 3	9.8	6	6.1	78.3	26.5	3	24.9	8.9	24.3	0.97	133
26	18/ M	kharra	GROUP 3	11	15.4	204	79.7	349	Tye 3	37	7.4	33.6	0.9	143
27	20/M	kharra	GROUP 3	9.1	9.7	11.2	69.8	29	Typ 3	23.4	8	22.1	0.94	126
28	40/M	kharra+ tobacco	GROUP 3	9.2	11	11.5	74.3	30.1	type 6	37.2	9.1	28	0.75	134
29	37/F	areca nut	GROUP 3	11	11	9.4	64.1	24.5	10	29.4	9.1	25.5	0.86	136
30	29/M	kharra	GROUP 3	7.1	6.6	7.4	83.2	29.3	Type 7	38.3	11.1	30.4	0.79	138
31	21/M	kharra	GROUP 3	7.3	8.9	11.3	68.8	27.6	Type 3	28.2	10.1	24.8	0.87	132
32	29/M	kharra	GROUP 3	10.9	11.1	11.5	75.2	27.4	2	27.5	2.7	26.6	0.96	132
33	26/M	kharra	GROUP 3	9.2	10.3	10.5	74	32.2	Type 6	22.9	8.1	22.3	0.97	134
34	32/F	areca nut	GROUP 3	8.7	7.9	7.2	63.5	26	6	24.8	5.7	25.9	1.04	131
35	33/F	areca nut	GROUP 3	11.1	10.5	10.7	67.3	29.4	1	26.4	6.5	23.9	0.9	132
36	41/M	kharra+ tobacco & lime	GROUP 3	13.4	14.5	12.9	81	34.3	Type 6	28.8	8.2	27.7	0.96	133
37	36/M	kharra	GROUP 3	10.1	11.1	10.5	73.8	30.4	Type 1	36.3	9.9	30	0.82	140
38	60/M	kharra+ tobacco+ bidi	GROUP 3	10.1	10.3	8.6	71.7	27.3	type 11	30.8	9.7	24	0.77	127
39	30/F	kharra	GROUP 3	12.8	9.7	10.4	70.9	30.1	type 2	34.3	6.8	25.3	0.73	128
40	35/M	kharra	GROUP 3	11.5	8..7	9.8	73.2	30.5	2	32.4	11.3	24.5	0.75	132

GROUP C4														
1	35/M	kharra	GROUP 4	9.5	8.7	11	76.5	29.5	TYPE 6	34.8	10.5	28	0.8	129
2	33/M	kharra	GROUP 4	8.6	11.1	12.1	84.3	28.9	TYPE 7	36.3	11.9	26	0.71	127
3	26/M	kharra	GROUP 4	12.8	8.1	10.9	71.1	30.9	Type 3	23.4	5.9	27.4	1.17	126
4	29/M	kharra	GROUP 4	8.4	6.4	7.1	72.9	32.5	type 6	28.4	6.4	26.7	0.94	137
5	27/M	kharra	GROUP 4	8.4	6.7	9.5	77.1	3.9	type 5	27.7	5.4	22.8	0.82	127
6	37/M	kharra+ tobacco & lime	GROUP 4	8.2	13.3	12.3	77.2	28.4	type 6	19.7	6.4	20	1.01	118

7	45/ M	kharra+ tobacco & lime	GROUP 4	9.3	11.6	12.5	77.1	33.9	type 6	23.3	5.2	22.1	0.94	125
8	22/M	kharra	GROUP 4	7.8	9.1	9.4	69	30.8	type 6	23.6	6.7	23.7	1	130
9	24/M	kharra	GROUP 4	8.7	7.6	10.8	75.5	33.3	7	31.4	7.5	21.8	0.69	130
10	55/M	kharra+ tobacco & lime+ bidi	GROUP 4	11.7	13	14.3	78.5	28.5	6	25.2	8.1	26.9	1.06	136
11	53/M	kharra	GROUP 4	7.3	7.9	7.4	79.7	31.9	1	35.5	13.2	22.9	0.64	125
12	23/M	kharra	GROUP 4	17	14.3	14.6	71.4	26.5	2	31.4	4.6	30.2	0.96	133
13	22/M	kharra+ tobacco	GROUP 4	12.2	13.5	17.2	73.2	28.5	2	39.6	8.6	23	0.58	131
14	32/M	kharra	GROUP 4	9.9	12.6	10.1	72.1	30.9	3	26.7	10.1	24.5	0.91	131
15	22/M	kharra	GROUP 4	6.9	5.3	8.3	78.2	30.7	6	21.7	6.2	17.9	0.82	145
16	25/M	kharra	GROUP 4	6.8	6.2	9.4	72.6	29.5	1	31.3	8.4	20.6	0.65	127
17	28/M	kharra	GROUP 4	6.5	5.7	6.9	70.4	30.9	6	26.2	8.9	19.8	0.75	122
18	27/F	areca nut	GROUP 4	11.1	11.5	12.3	76.7	27	6	25.7	9.1	20	0.77	135
19	29/F	areca nut	GROUP 4	9.3	6.1	8.4	65.4	30.6	3	28.2	10.8	23.7	0.84	131
20	23/M	kharra	GROUP 4	9.2	12.7	14.4	70.9	30.7	7	27.2	7.3	22.8	0.83	125
21	32/M	kharra	GROUP 4	10.4	11.3	12.5076.4		31.4	1	32	8.5	26.4	0.82	130
22	20/M	kharra	GROUP 4	15.3	13.1	11.2	68.5	27.5	3	28	7	24.4	0.87	113
23	34/M	kharra	GROUP 4	9.7	11.3	9.8	71	28.4	6	29	7	21	0.72	123
24	28/F	kharra+ areca nut	GROUP 4	9	5.9	6.2	72.4	24.5	1	36.1	9.7	25.3	0.7	133
25	27/F	areca nut	GROUP 4	10.9	8.4	7.9	64.1	26.8	3	20.8	6.4	19.5	0.93	126
26	29/M	kharra	GROUP 4	11.9	11	11.9	69.8	25.4	1	26.2	8.8	29.3	1.11	134
27	55/F	kharra+ tobaco	GROUP 4	7.9	11.4	12.4	65.9	26.9	type 7	28.5	8.1	20.3	0.71	129
28	45/F	areca nut+ tobacco	GROUP 4	9.9	10.5	11.6	70	27.3	7	32.8	9	26.5	0.8	128
29	34/M	kharra	GROUP 4	7.2	6.8	6.9	76.8	34.1	2	27.8	5.6	22.1	0.79	127
30	45/M	kharra+ tobacco & lime	GROUP 4	5.9	8.8	13.6	63.9	36.7	1	34.5	11.2	28	0.81	133
31	40/M	kharra	GROUP 4	8.5	9.7	12.1	73.8	33.8	7	35.7	7.9	25.1	0.7	117
32	30/M	kharra	GROUP 4	9	9.7	11.2	84.5	32.8	2	38.7	6	17.7	0.45	132
33	50/F	areca nut	GROUP 4	6.8	12.6	11.8	74.1	27.9	7	42.4	9.9	26.2	0.61	128
34	50/M	kharra+ tobacco & lime	GROUP 4	9.9	11.9	10	74.3	25	type 1	32.5	10.6	31.7	0.97	142

35	34/M	kharra	GROUP 4	9.6	12.9	11.1	75.9	30.7	type 1	27.8	8.5	25.2	0.9	128
36	42/M	kharra	GROUP 4	7.3	10.7	13	75.8	32.2	1	33.8	13.3	25	0.73	129
37	24/M	kharra	GROUP 4	9.2	7.9	7	66.9	29.5	3	25.8	7.9	25.2	0.97	125
38	49/M	kharra	GROUP 4	7.6	10.6	9.8	81.2	29.9	2	38.7	8.5	28.9	0.74	128
39	48/M	kharra	GROUP 4	9.9	11.4	10.5	75.6	25.4	3	35.5	10.2	30	0.84	130
40	37/M	kharra	GROUP 4	10.4	9.9	10.2	74.6	24.8	6	31.4	9.9	29.9	0.95	128

GROUP B														
1	48/M	kharra+ tobacco & lime	GROUP B	11.1	14.6	18.8	78.5	26.6	7	36.5	9.1	24.5	0.67	115
2	38/F	areca nut	GROUP B	9	6.9	6.6	74.9	27.6	1	32.3	7.7	24.3	0.75	130
3	17/M	kharra	GROUP B	9.7	11.3	9.9	71.4	28.5	1	35.5	9.7	25.3	0.71	131
4	35/M	kharra	GROUP B	15.9	12.8	13.6	79.6	30.2	1	34.5	9.4	31.6	0.91	127
5	44/F	areca nut+ tobacco	GROUP B	16.1	14	13.3	75.5	30.3	6	25.3	5.8	25.4	1	121
6	55/F	areca nut	GROUP B	11.2	12.9	10.6	78.3	26.6	10	39.1	10.5	28.9	0.73	131
7	58/M	kharra+ tobacco & lime	GROUP B	8.6	12.2	8.9	85.3	28.9	1	34.8	11.9	28.1	0.8	131
8	29/M	kharra	GROUP B	13.3	17.9	17.6	71.3	31.1	7	36.9	9.6	36.9	1	135
9	29/M	kharra	GROUP B	13.6	13.7	15.5	65.9	31.8	1	30.3	10.6	31.8	1.04	133
10	52/M	kharra+ areca nut	GROUP B	17.9	17.6	16.6	80.7	27.4	2	31.7	7.1	27	0.85	131
11	49/M	kharra	GROUP B	7.6	8	10.7	87	27.3	4	30.6	3.7	26.7	0.87	133
12	52/M	kharra+ tobacco	GROUP B	10.6	13.7	13.9	89.9	28.6	1	41.3	13.9	30	0.72	130
13	62/F	kharra+ areca nut	GROUP B	10.9	15.6	15.6	75.9	28.5	1	32.4	11.3	27.6	0.85	132
14	55/M	kharra	GROUP B	9.6	14.7	9.9	84.4	30.8	1	33.7	11.4	26	0.77	131
15	50/F	areca nut	GROUP B	10.2	5.6	4.9	70	29.1	3	20.9	8.5	21.2	1.01	121
16	24/M	kharra	GROUP B	11.1	12.4	9.4	81.3	29.8	1	29.6	11.9	23.9	0.8	132

17	30/M	kharra	GROUP B	15.7	9.7	9.4	77.9	34.8	9	33.5	4.8	25.2	0.75	122
18	26/M	kharra	GROUP B	8.4	12.1	11.8	80.2	31.3	1	37	11.2	30.5	0.82	131
19	32/M	kharra	GROUP B	15.4	15.2	15.1	68	31	3	30.4	6.9	27	0.88	122
20	27 /M	kharra	GROUP B	17.6	16.8	16.4	76.4	33.2	Type 1	32.4	7.1	30.6	0.94	134
21	18/M	kharra	GROUP B	14.8	10.2	11.6	76.5	30.3	2	32.2	5.9	31.4	0.97	133
22	21/M	kharra	GROUP B	14.4	11.5	10.5	76.7	27.7	3	36.2	7.8	29.6	0.81	125
23	37/M	kharra	GROUP B	13.6	13.9	14.1	70.6	30.7	Type 10	29.6	8.4	29.2	0.98	131
24	27/F	areca nut	GROUP B	13.8	11	9.8	75	25.5	type 7	35.9	6.8	29.2	0.81	133
25	55/M	kharra	GROUP B	18.6	10.7	12.8	74.5	27.7	5	28.2	10.6	32.1	1.13	128
26	21/M	kharra	GROUP B	14.7	15.3	14	73.6	29.7	2	35	3.3	25.9	0.74	121
27	27/M	kharra	GROUP B	16.9	15.7	14.8	74.3	25.1	6	32.2	9.9	35.8	1.11	134
28	22/F	areca nut	GROUP B	13.3	14.5	12.9	76.5	29.5	2	33.5	13.5	36	1.07	130
29	41/M	kharra+ tobacco & lime	GROUP B	15.2	14.8	14.5	77.2	29.4	3	31.4	9.5	34	1.08	132
30	35/F	areca nut	GROUP B	12.5	13.8	14.1	76.2	28.4	1	34	10.2	35.2	1.03	128
31	21/M	kharra	GROUP B	17	12.1	15.6	79	31.1	Type 1	33.7	8.9	30	0.89	140
32	35/F	areca nut	GROUP B	16.8	14.5	14.5	77.6	29.5	1	32.5	11.4	33.8	1.04	128
33	40/F	areca nut	GROUP B	12.8	9.7	10.4	70.9	30.1	type 2	34.3	6.8	25.3	0.73	128
34	38/M	kharra	GROUP B	15.9	12.8	13.6	79.6	30.2	1	34.5	9.4	31.6	0.91	127
35	40/M	kharra	GROUP B	14.8	13.7	12.8	77.8	31.6	3	32.1	9.4	33.2	1.03	130
36	32/M	kharra	GROUP B	12.5	11.4	11.2	75.8	29.5	1	34.1	10.8	33.7	0.98	132
37	50/M	kharra+ tobacco & lime	GROUP B	14.7	7.5	8.9	64	25.7	1	24.8	6.8	23.7	0.95	126
38	45/F	areca nut	GROUP B	13.3	17.9	17.6	71.3	31.1	7	36.9	9.6	36.9	1	135
39	55/F	kharra+ areca nut	GROUP B	15.3	8.8	9.5	68.3	26.6	type 1	33.2	7.5	29	0.87	123
40	38/M	kharra	GROUP B	14.4	12.8	14.1	78.5	25.8	Type 6	41.2	9	28.5	0.69	128
GROUP A														

1	20/M		GROUP A	17.7	15	14.1	85	30.3	1	37.9	10	40.6	1.07	142
2	26/M		GROUP A	16.8	15.4	15	83.5	32.1	1	41	11.3	33.4	0.81	138
3	44/F		GROUP A	18.4	14.2	14.6	79.4	34	3	32.3	10.2	31.4	0.97	132
4	25/F		GROUP A	13.3	14.5	12.9	76.5	29.5	2	33.5	13.5	36	1.07	130
5	33/F		GROUP A	11.2	10.5	10.9	71.3	28.5	1	31.2	10	31	0.99	128
6	35/M		GROUP A	14.7	12.8	13.1	72.4	31.5	3	28.4	9.6	29	1.02	125
7	28/F		GROUP A	12.1	8	7.8	73.2	24.8	1	29.8	6.2	25.4	0.85	137
8	42/M		GROUP A	13.4	12.4	12.8	68.1	23.5	2	30.6	10.1	31	1.01	128
9	24/M		GROUP A	15.2	9.8	9.5	69.3	27.4	1	33.1	8.5	29.6	0.89	125
10	31/M		GROUP A	16.8	10.4	12.5	72.4	28.6	3	29.5	10.2	28.4	0.96	128
11	54/M		GROUP A	18.6	10.7	12.8	74.5	27.7	5	28.2	10.6	32.1	1.13	128
12	29/M		GROUP A	16.2	12.2	13.6	72.3	30.5	2	32.1	8.9	33	1.02	134
13	35/M		GROUP A	14.1	13.8	13.2	69.6	25.4	3	28.4	9.9	30.2	1.06	126
14	18/F		GROUP A	12.1	11.5	10.6	78.2	34.2	1	32.4	11.3	33.6	1.03	135
15	28/F		GROUP A	13.2	12.5	12.4	69.8	34.5	1	31.5	12.1	32.8	1.04	132
16	42/M		GROUP A	17.1	14.8	14.9	73.5	29.5	3	30.2	10	31.5	1.04	129
17	28/M		GROUP A	14.5	13.2	13.5	72.8	25.9	2	32.2	8.5	30.6	0.95	130
18	63/M		GROUP A	15.4	14.5	14.3	73.2	30.2	1	32.1	11.5	33.4	1.04	132
19	32/F		GROUP A	13.2	12.8	11.9	72.1	29.5	3	30.1	9.8	31.2	1.03	128
20	48/M		GROUP A	17.4	15.6	15.4	73.9	30.4	1	33.4	12.4	34.1	1.02	135
21	29/M		GROUP A	16.8	14.5	13.9	73.4	32.1	4	33.1	11.8	34.1	1.03	132
22	19/M		GROUP A	17.4	16.8	16.5	74.9	34.5	1	34.1	12.4	34	0.99	136
23	22/F		GROUP A	14.5	13.5	13.2	72.6	24.8	1	30.1	10.5	31.4	1.04	127
24	35/F		GROUP A	15.2	13.2	13.3	78.6	31.8	1	31.3	12.4	33.4	1.06	135
25	24/M		GROUP A	16.1	15.4	15.2	70	29.5	3	32.4	10.1	33.1	1.02	130
26	18/M		GROUP A	15.6	14.5	14.8	74.8	33.4	1	33.4	12.1	34	1.01	137
27	28/F		GROUP A	13.2	10.1	10.3	71.2	32.2	1	29.2	10.9	31	1.06	125
28	64/F		GROUP A	16.4	15.4	15.2	72.1	34.2	4	31.4	10.2	34	1.08	131
29	30/F		GROUP A	14.5	11.2	11.1	69.8	29.7	3	28.7	9.8	30	1.04	128

30	42/M		GROUP A	13.5	10.2	10.5	72.5	31.4	1	31.5	12.4	32.8	1.04	132
31	25/M		GROUP A	15.2	14.1	13.9	70.2	29.6	1	29.5	10.3	30.4	1.03	127
32	22/F		GROUP A	14.4	13.9	13.5	70.2	29.9	2	31.2	10	33	1.05	131
33	26/F		GROUP A	12.1	10.2	10.2	71.3	28.4	1	30.3	11.2	31.2	1.02	130
34	32/M		GROUP A	15.9	12.8	13.6	79.6	30.2	1	34.5	9.4	31.6	0.91	127
35	35/F		GROUP A	12.3	11.2	11.5	68	26.8	2	30.2	8.6	31.2	10.3	125
36	45/M		GROUP A	16.2	14.2	13.9	76.2	29.5	1	32	10.2	31.8	0.99	131
37	29/M		GROUP A	15.2	13.3	13.3	78.5	31.8	1	31.3	12.4	33.2	1.06	135
38	31/F		GROUP A	14.5	12.2	11.5	70.2	31.2	3	28.3	9.9	30	1.05	129
39	19/F		GROUP A	15.2	14.6	14.4	75.2	32	1	34.5	11.2	35	1.01	134
40	35/M		GROUP A	21.4	18.7	19.2	81.3	34.5	type 1	33.5	6.1	27.6	0.82	132