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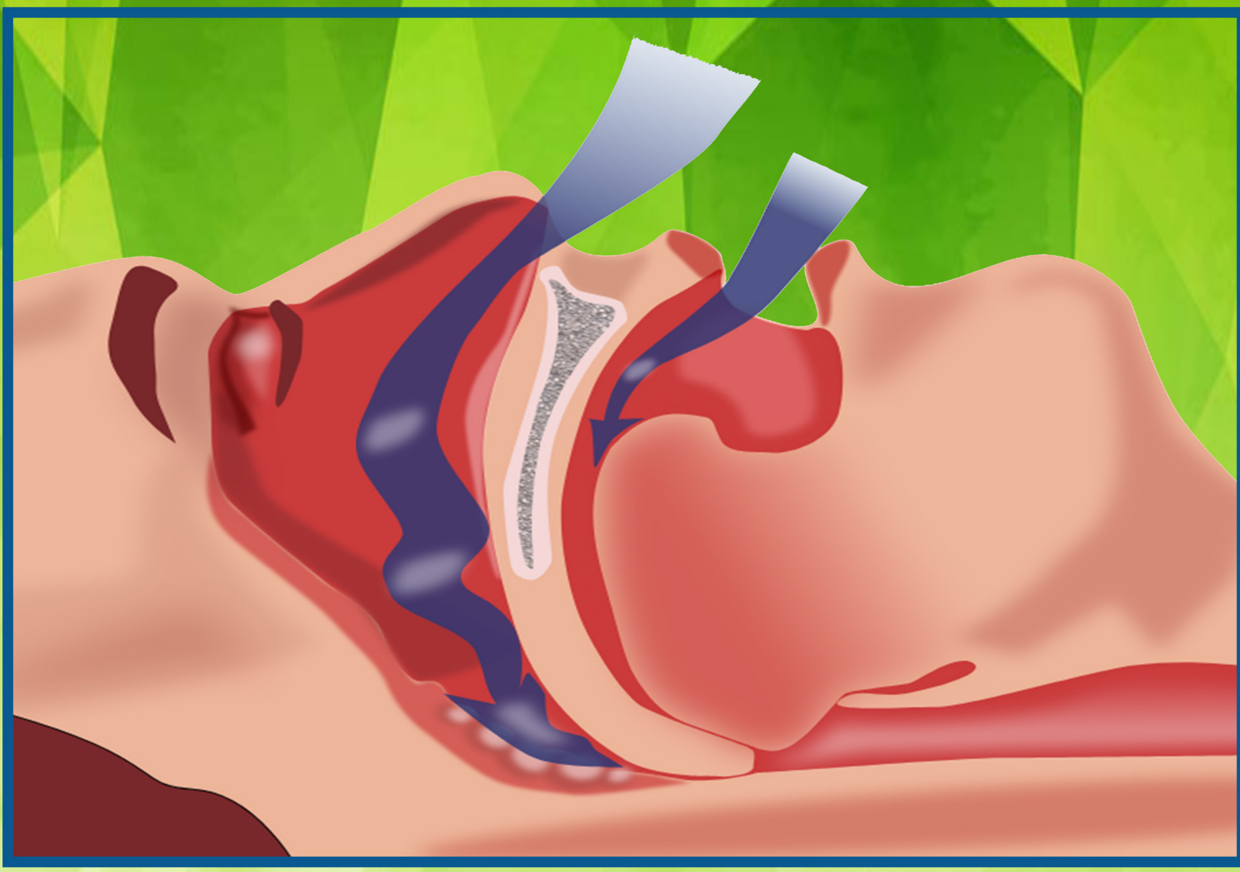

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Preface

Obstructive Sleep Apnoea is one of the most commonly encountered sleeping disorder among the human population. Thus it is very important to educate the community about this very condition that made me to simplify the knowledge about Obstructive Sleep Apnoea in a form of the first edition of this EBook. Being an Orthodontist, our field in Dentistry is very dynamic with changes occurring at rapid pace. Orthodontics has proved itself to be much more than a cosmetic field as in terms of treating Temporomandibular disorders, Facial growth modulation and Correction of Upper Airway problems encountered either by unusual habits related to tongue and other facial musculature and as well as unusual jaw positioning. The recent interest has been developed regarding OSA and Snoring as a fact that this condition has a close association with the malocclusions that are being analysed in the patients that require orthodontic treatment especially in Class II growth pattern.

All attempts have been made to simplify the presentation while not compromising the scientific basis of the information discussed. Understanding has been further simplified by the liberal use of line diagrams and photographs. Noteworthy points have been referenced clearly.

The ultimate objective of this book will not be fulfilled unless it awakens a genuine love for this fascinating subject in the readers heart. I hope my work will be appreciated and accepted by the Dental and Medical community.

J&K
11 August 2018 Uzma Nazir.

Contents

Introduction

Obstructive sleep apnoea (OSA) is a sleep-related breathing disorder that involves a decrease or complete halt in airflow despite an ongoing effort to breathe. It occurs when the muscles relax during sleep, causing soft tissue in the back of the throat to collapse and block the upper airway. This leads to partial reductions (hypopnoea) and complete pauses (apnoeas) in breathing that last at least for 10 seconds during sleep. Most pauses last between 10 and 30 seconds, but some may persist for one minute or longer. This can lead to abrupt reductions in blood oxygen saturation, with oxygen levels falling as much as 40 percent or more in severe cases.

The brain responds to the lack of oxygen by alerting the body, causing a brief arousal from sleep that restores normal breathing. This pattern can occur hundreds of times in one night. The result is a fragmented quality of sleep that often produces an excessive level of daytime sleepiness [1]. Most people with OSA snore loudly and frequently, with periods of silence when airflow is reduced or blocked. They then make choking, snorting or gasping sounds when their airway reopens. Guilleminault, et al. studied the relation between maxillary constriction and the etiology of OSA and reported a familial tendency of narrow high arched palates among the relatives of OSA patients [2]. Cistulli & Sullivan have shown high prevalence of OSA among the patients with Marfans syndrome [3]. As the general public and our specialty better recognize the interactions between craniofacial form and overall health, orthodontists might be expected to become proficient in a broader range of health issues. Snoring and obstructive sleep apnoea is such a field in which more than 80 different oral appliances are currently available to treat snoring and sleep apnoea, and the public's demands on orthodontists continue to increase. This dissertation contains articles of particular interest to orthodontists, who, based on their knowledge of functional appliances and skills in evaluating jaw position and tooth movement, are ideally suited to provide oral-appliance therapy.

Under current Canadian guidelines, patients who require oral appliances for treatment of snoring and obstructive sleep apnoea are referred directly to orthodontists by an attending sleep physician or a family physician after an assessment of the sleep disorder. The assessment might include at-home or in-hospital monitoring. A differential diagnosis of snoring or the type and severity of sleep-disordered breathing is communicated to the orthodontist at the time of referral. The orthodontist examines the patient to determine which oral appliance is best suited to his or her needs. The appliance is constructed, fitted, adjusted, and gradually titrated (advanced forward) over several weeks or months until the snoring is reduced to an acceptable level, the symptoms of daytime sleepiness are reduced, or the patient cannot tolerate further advancement. The Patient is then referred back to physician for follow up assessment to verify the effectiveness of oral appliance.

Recently, clinicians in this field have observed occlusal changes with long-term wear of oral appliances. In addition, models that predict which patients are most likely to succeed with oral appliances are required. Almeida, et al. [4] documented some changes observed in the dentition after long-term wear of oral appliances. It appears that the occlusal changes are predominantly dental and occur after more than 2 or 3 years of wear. Marklund [5] found a reduction in overjet over time associated with initial bite depth, type of device, and nasal congestion. Based on cephalometric comparisons, Otsuka, et al. [6] documented a better response to therapy in post-titration subjects who exhibited a more anterior velopharyngeal wall, a larger radius of curvature of the airway, and an increase in velopharyngeal size. Orthodontists who get involved in this form of therapy are often surprised at how grateful their patients are after only a few nights of sleep without interruption and the subsequent restoration of adequate sleep. Substantially changing the quality of a patient's life with an oral appliance can be a very rewarding experience

Terminology

a) Apnoea index (AI) is the number of apnoea per hour of sleep, with 5 or less considered normal [1].
b) Apnoea-hypopnoea index (AHI) is the number of apnoea and hypnoses per hour of sleep. Ten or less is usually considered to be normal.
c) Central sleep apnoea is the cessation of airflow from lack of respiratory effort.
d) Epworth sleepiness scale (ESS) is a reliable and validated subjective assessment of daytime sleepiness. A score greater than 10 on this self-administered questionnaire indicates excessive sleepiness.
e) FDA 510k is a premarket notification that a medical device manufacturer must submit to the Food and Drug administration. It allows the FDA to determine whether the device is equivalent to one in commercial distribution before May 28, 1976. New or modified devices must be supported with safety and effectiveness data that may include material composition, biocompatibility, and clinical testing.
f) Hypopnoea is an abnormal reduction of airflow starting as central followed by obstructive.
g) Multiple sleep latency test (MSLT) is an objective measure of daytime sleepiness. A time greater than 10 minutes is oftentimes defined as normal.
h) Obstructive sleep apnoea (OSA) is the cessation of airflow despite adequate effort to breath.

i) Polysomnography is the science dealing with the physiology of sleep and the definitive objective means of diagnosis of sleep apnoea and related disorders. Activities monitored during a sleep study are brain waves (EEG), eye movements (EOG), muscle activity (EMG), heart-beat (EKG), blood oxygen levels (SaO¬2¬), and respiration. Polysomnographic markers include total sleep times, sleep efficiency, sleep stage distribution, arousal index (sleep fragmentation), and snoring frequency and intensity [7].
j) Respiratory disturbance index (RDI) is another term for AHI. The usual definition of slight OSA is an RDI of 5 to 14, moderate OSA is an RDI of 15 to 30, and severe OSA is an RDI of >30.1
k) Snoring is breathing through a narrowed upper airway space during sleep with harsh noises, as caused by the vibrating of the soft palate.
l) Upper airway resistance syndrome is an incomplete upper airway obstruction without apnoea's or hypopnoea. Snoring, inadequate sleep, and daytime sleepiness characterize this condition [7].

Obstructive Sleep Apnoea

Obstructive sleep apnoea (OSA) is a relatively common disorder that affects people of all ages, but is most prevalent among the middle-aged and elderly. Affected individuals experience repeated collapse and obstruction of the upper airway during sleep, which results in reduced airflow (hypopnoea) or complete airflow cessation (apnoea), oxygen desideration, and arousals from sleep [8]. Adverse clinical outcomes associated with OSA include: cardiovascular disease, hypertension, non-insulin dependent diabetes, and increased likelihood of motor vehicle and other accidents due to daytime hyper somnolence. Studies estimate the prevalence of OSA at approximately 10 to 20 percent of middle-aged and older adults. Evidence also indicates that these rates are rising, likely due to increasing rates of obesity.

Epidemiology

At present, the estimation of the prevalence of sleep disorders in the general population varies to some degree. It is reported that 40 million people have some type of chronic sleep disturbance, and 20 to 30 million have intermittent sleep-related problems. A frequently cited study estimates that 4% of middle-aged men and 2% of middle-aged women in the general population meet the minimum criteria for sleep apnoea syndrome. the same study cites the findings from the Wisconsin Sleep Cohort Study, a population-based study of middle-aged adults, which estimates that 24% of men and 9% of women have sleep-disordered breathing that meets the criteria of an apnoea-hypopnoea index of 5 or greater and have reported daytime hyper somnolence as a comparison, it is now estimated that the national incidence for diabetes, as reported by the Centres for Disease Control (U.S), is approximately 6.9% of the population. Another study estimated that as many as 93% of middle-aged men and 82% of middle-aged women of the general population may have undiagnosed moderate to severe sleep apnoea [9].

A prevalence of 2% in the adult female population and 4% in the adult male population has been reported by Young and co-workers. More recent figures up to 4% established OSAHS as second only to asthma in the prevalence of chronic respiratory disorders, depending on the diagnostic criteria used. The morbidity of OSAHS relates principally to the cardiovascular system. Rigorous epidemiologic studies have shown that sleep apnoea is a risk factor for the development of arterial hypertension, independent of associated obesity, alcohol intake, sex, and age.

Classification of OSA

Sleep apnoea is classified as central, obstructive, or mixed, and it may be mild, moderate, or severe [10].

Central sleep apnoea: Central sleep apnoea (CSA) occurs when the brain fails to send the appropriate signals. To the breathing muscles to initiate respirations. It is often secondary to central nervous system diseases, such as infarction and infection involving the brain stem, orneuromuscular diseases involving respiratory muscles. In primary alveolar hypoventilation and obesity hypoventilation syndrome (e.g, Pickwickian Syndrome), there is a reduction of ventilatorychemo sensitivity and a decrease in central ventilatory drive. In some cases, CSA is a component of periodic breathing (eg, Cheyne- Stokes respiration). This type of apnea is common to neurological injury. Rarely, sleep apnea is due to primary brain stem medullary failure or Ondine's curse. First, evidence of central sleep apnea has been observed by Badr in 1995. Central breathing instability has been well established to contribute to the development of central sleep apnea, particularly in patients with severe congestive heart failure as documented by Leung in 2001, later by Xie in 2002.

Obstructive sleep apnoea: Obstructive sleep apnoea is characterized by the cessation of airflow with persistence of ventilatory effort, caused by collapse of soft tissue structures in the oropharynx or hypopharynx.

Possible Sites of Obstruction

Nose:

a) Deviated septum
b) Enlarged turbinates
c) Polyps

Nasopharynx:

a) Enlarged adenoids

Pharynx:

a) Enlarged tonsils
b) Enlarged uvula or soft palate
c) Enlarged base of the tongue
d) Tongue base falling into pharyngeal airway

Submucosal fat or redundant mucosa: Larynx (voice box): Laryngopharyngeal reflux changes with severe posterior commissure swelling Figure 1.

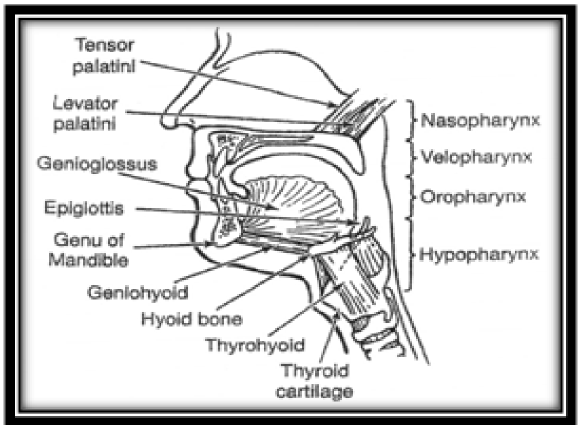

Figure 1: Anatomy of Pharyngeal Airway.

Main Site of Obstruction

Most of the obstructions were seen in the retroglossal and retropalatal tissues of the oropharynx.

Mixed: Mixed apnoea starts as unobstructed apnoea, which is quickly followed by thoracoabdominal movements with upper airway obstruction. Mixed apnea starts as central apnea, quickly followed by thoracoabdominal movements and upper airway obstruction.Mixedapnoea occurs more often than central but less often than obstructive apnoea; it should be treated as an obstructive apnoea Figure 2.

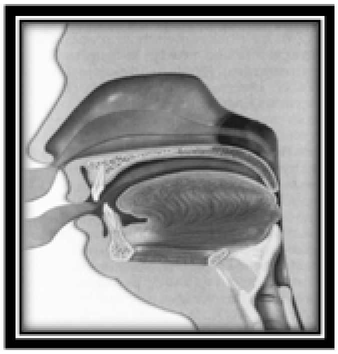

Figure 2: Sites of Obstruction.

Types of OSA

A common measurement of sleep apnea is the apnea-hypopnea index (AHI). This is an average that represents the combined number of apneas and hypopneas that occur per hour of sleep.1o

Mild OSA: *AHI of 5-15*

Involuntary sleepiness during activities that require little attention, such as watching TV or reading

Moderate OSA: *AHI of 15-30*

Involuntary sleepiness during activities that require some attention, such as meetings or presentations

Severe OSA: *AHI of more than 30*

Involuntary sleepiness during activities that require more active attention, such as talking or driving

Risk Groups

a) People who are overweight (Body Mass Index of 25 to 29.9) and obese (Body Mass Index of 30 and above)
b) Men and women with large neck sizes: 17 inches or more for men, 16 inches or more for women
c) Middle-aged and older men, and post-menopausal women
d) Ethnic minorities
e) People with abnormalities of the bony and soft tissue structure of the head and neck
f) Adults and children with Down Syndrome
g) Children with large tonsils and adenoids
h) Anyone who has a family member with OSA
i) People with endocrine disorders such as Acromegaly and Hypothyroidism
j) Smokers
k) Those suffering from nocturnal nasal congestion due to abnormal morphology, rhinitis or both.

Review of Literature

Sir William Osler in 1918 coined the term "Pickwickian" to refer to obese, hypersomnolent patients Hofrath in Germany and Broadbent in United States in 1931 simultaneously published methods to obtain standardized head radiograph. This development enabled orthodontists to adopt the field of cephalometry from anatomists and anthropologists who had monopolized craniometric studies, during the nineteenth century. The salient standardization parameters during initial days included radiographic film kept on left side close to head, distance between radiographic film and x-ray source at 5ft constant and recording the cephalogram with Frankfort horizontal plane oriented parallel to the floor. It became clear that cephalometrics could be used to evaluate dentofacial proportions and clarify the anatomic basis of malocclusion. Ever since its inception, cephalometric analysis was carried out not only on radiographs but on manual tracings that emphasised the relationship of selected points. From the very beginning cephalometric analysis and concepts revolved around comparing the patient to normal reference group, so that differences between the patient's actual dentofacial relationship and those expected for his or her racial and ethnic group are revealed [11].

Downs WB [12] in 1948 developed a cephalometric analysis at the University of Illinois. The control material studied was derived from twenty living individuals, ranging in age from 12 to 17 years. Models, photographs, cephalometric and intraoral roentgenograms were taken of each. All individuals possessed clinically excellent occlusions. Downs pioneering work inspired many orthodontists to establish various normal reference standards. Brodie [13] in 1950 pointed out that as man assumed an upright posture the head had to be balanced on the vertebral column. This is attained by equal anterior and posterior muscle tension relative to the occipital condyles. In the accomplishment of this delicate cranial balance and posture, the hyoid bone plays an important and active part.

Elbert W King [14] in 1952 noted that changes in head position lead to changes in the position of the hyoid bone in the same person. If the head is extended back, then the hyoid bone moves back; if the head is tipped forward, then the hyoid bone moves forward. This longitudinal growth study has been conducted on the changes occurring between skeletal landmarks which are held to be responsible for the growth of human pharynx. The materials included roentgenographic records obtained on twenty-four males and twenty-six females over the period from three months to sixteen years of age by the use of Broadbent Bolton cephalometer.
He concluded that:-

a) Dimensional increase of the nasopharynx by growth at the spheno-occipital junction was shown to be minimized by forward growth of the anterior arch of the atlas.
b) From three months to sixteen years the anteroposterior growth between the atlas and the posterior nasal spine amounted to only 3.8mm in male and 2.6mm in female.
c) The distance between the hyoid bone and the cervical vertebrae was constant until puberty when the hyoid bone moved forward slightly.
d) Growth in length of the pharynx was continuous for the age period studied with a slight prepuberal spurt in the female and a slight postpuberal spurt in the male.

Burwellet Alin [15] 1956 described several obese, hypersomnolent patients with respiratory and cardiac failure coined the term "Pickwickian Syndrome". Gastaut, et al. in 1965 described obstructive sleep apnoea and associate it with hypersomnia in obese patients in Pickwickian syndrome. This French group of incestegators were the first to co-relate OSA to Obese subjects.

Remmers & Sauerland [16] in 1970 described respiratory control of the upper airway and reduced activation during sleep. They found that maintaining the upper airway will enhance breathing during sleep.

Fujita [17] in 1981 reported the first cases of OSA treated by soft palate surgery (uvulopalatopharyngoplasty UPPP). This procedure was found effective in eliminating snoring; however, it is not necessarily curative for OSA, because areas of the airway other than the soft palate also collapse in most patients with this sleep disorder . The success of this technique may range from 30 to 60 percent.

Sullivan [18] in 1981 described the dramatic effect of nasal continuous positive airway pressure (CPAP) on OSA. CPAP became the dominant therapy in the 1990s. Approximately 55 percent success rate was observed by treating the patients of OSA with CPAP. Despite these early examples, the use of oral appliances for treating sleeping disorders was not considered until the 1980s. Initial publications include a description of the tongue-retaining device of Samelsen and Cartwright in 1982, an orthodontic mandibular appliance by Soll and George in 1983, and an Esmark mandible-advancing appliance by Kloss and Meier-Ewert in 1984.

Steiner CC in 1953 selected what he considered to be the most meaningful parameters and developed a composite analysis, which he believed would provide the maximum clinical information with the fewest number of measurements. He concluded that angle of great importance is the difference of the angles SNA and SNB, which is the ANB angle, because it gives direct reading of the relationship of chin to other structures of face. The mandibular plane is drawn between gonion and gnathion. The mandibular plane angle is formed by relating it to the anterior cranial base (SN). The mean reading for this is 32 degrees. The mandibular plane angle still remains the crucial cephalometric parameter for assessing vertical relation of the mandible with cranial base.

Tweed CH [19] in 1954 developed a cephalometric analysis for orthodontic treatment planning based on a triangle formed by Frankfort horizontal plane, Mandibular plane, and long axis of mandibular incisor. His analysis was based on a study he conducted on forty five individuals. He proposed the mean values of FMA, IMPA and FMIA – as 24.9°, 86.6° and 68.6° respectively.

Downs WB in 1956 was the first to introduce the truly classical full scale cephalometric analysis. The components of this analysis formed the bed rock from which many of the future analysis developed. In his opinion cephalometric recording is a method of accurately expressing relationships of the components of the face and the changes which occur during growth and development. This paper has endeavoured to analyze and differentiate between good and poor dentofacial profiles.

Grant [20] in 1959 studied the position of the hyoid in Class I, II and III malocclusion. In this study one cephalometric roentgenogram for each subject was selected from an orthodontic school file. Grant concluded that the hyoid position is constant in the three types of malocclusion; he also said that the musculature and not the occlusion of the teeth, determines the position of the hyoid. He found that the hyoid level, in his teenage sample, was midway between the third and fourth cervical vertebrae.

Bergland O in 1963 anatomically divided the pharynx into two parts: an upper region (the nasopharynx) and a caudal area (the oropharynx). In dry skull material the bony nasopharynx is a conelike space that extends three dimensionally downward from the vomer's most dorsal contact point on the body of the sphenoid (hormion) to the level of the hard palate and theforamen magnum. During the growth process, this structure increases its volume by about 80%. Transverse pharyngeal growth (measured as an increase in bihamular width) seems to level off at the end of the second year of life, but the choanal width (measured as the maximum distance between the medial pterygoid plates) increases moderately until maturity by about 23% and even in adolescence an acceleration can be observed. The major part of nasopharyngeal growth occurs in a vertical direction, particularly caused by the downward growth of the palate and the growth effects of spheno-occipital synchondrosis which is also in a vertical direction. According to Bergland, naso-pharyngeal height will increase from the age of 6, until puberty approximately by 38%. This increase in height plays a major role in increasing the bony space in this region during growth, and will continue until puberty (up to 18 in boys and 13 in girls). The mode of growth is a remodelling process at the medial pterygoidlaminae. For the pharynx, as for the face, different morphologic types and related growth behavior can be found. The posterior cranial base (the clivus) occupies a diagonal position in the cranium and makes up the posterior roof of the gable like bony nasopharynx. As a consequence, its growth will influence the horizontal as well as the vertical pharyngeal dimension. Which of the component dominates depends entirely on its inclination. An obtuse cranial base angle will open up the anteroposterior dimension of the pharynx, whereas an acute angle will contribute more to an increase in height.

Bench [21] in 1963 studied the growth of the cervical vertebrae and related structures. He found that as the child develops, the hyoid moves downward in conjunction with cervical vertebra growth. The level of the hyoid drops from the third cervical vertebra at age 3 to the fourth cervical vertebra in adulthood.

James Bosma in 1963 drew attention to postnatal maturation of the conspicuous oral and pharyngeal actions in feeding and in speech. Of greater significance, however, is the maturation of this anatomical region in two other closely related functions: (1) accomplishing a patent pharyngeal airway and (2) participation in postural function of the head and neck. The pharyngeal function of airway maintenance has been considered in developmental perspective. It has also been recognized as a mechanism that is liable to disability, like in infants having the Pierre Robin syndrome. Stabilization of the lateral and posterior pharyngeal walls is the resultant of the competing actions of the pharyngeal constrictors and of the pretracheal muscles, which elongate the pharynx by their traction upon the larynx and the hyoid bone, to which the mesopharynx and the hypopharynx are attached. Stabilization of the tongue, which is the anterior wall of the mesopharynx is the resultant of multiple and complex suspensions from the basicranium, styloid, posterior digastric muscles, and from the mandible by the submental and tongue muscles. The anterior displacement of the mandible itself, as a principal reference or origin for this suspensory arrangement, is determined by the external pterygoid muscles and increasingly with postnatal maturation by development at the temporomandibular joint. Another pterygoid motor element the tensor veli-palatini is apparently strategic in ventral displacement of the soft palate, which is essential to the patency of the epipharynx. Patency of the mesopharynx is determined most immediately by the tongue, which is positioned by its extrinsic or suspensory muscles in relation to the mandible, hyoid, and basicranium.

According to recent concept, stabilization of the pharynx as an airway precedes the stabilization of the head and neck in upright posture. These are indicated particularly by the stabilization of the hyoid bone in relation to mandible, basicranium, and cervical spine.

Schudy FF [22] in 1964 stated that the proportion of facial depth has not only a direct bearing upon facial type but also a direct influence upon vertical overbite and function. The interplay of anterior vertical facial growth increments and posterior vertical growth increments, together with anteroposterior growth is responsible for normal occlusions as well as malocclusions.

The principal thesis of this study was that vertical dimension is the most important dimension to the clinical orthodontist and those vertical dysplasias are inseparably related to both open and closed bites. According to author these vertical dysplasias are due to in harmonies in vertical growth, which are reflected in SN-MP angle and the occlusal plane to mandibular plane angle (OM). This study concluded the following:-

a) The average ratio between the height of the face and the depth of the face is about 76%. In the retrognathic group the depth was only 70% of the height and in the prognathic group the depth was 80%.

b) The ratio between the total anterior face height and the total posterior face height (perpendicular from SN to MP through Ar) was found to be 62.91% in average group, 57.23% for the retrognathic and 69.28% for the prognathic group.
c) Deep overbites are associated with extreme prognathia and mild overbites or open bites are associated with retrognathia.

Finally it was concluded that morphological types of the human face should be based on the angle of facial divergence.

Stepovich ML in 1965 reported that hyoid bone does not articulate with another bone and is completely suspended by ligament and muscle. He opined that it is unrealistic to expect the hyoid to stand still at the same spot each time that a roentgenogram is taken. The bone would always show some movement. The head can be stabilized, swallowing and breathing can be controlled, the tongue can be immobilized, the spine can be kept straight and the shoulders level, but not all to the same degree. Some individual variation from film to film may have to be accepted in dealing with hyoid measurements, therefore when roentgenograms of the same person were taken at different time intervals, the hyoid bone was found to be positioned differently in each film. For the first time, a technique was developed to measure the hyoid bone in three positions: vertically, horizontally and angularly. The hyoid plane was described for the first time.

Ingervall in 1970 found a positive correlation (although not always significant) between the anteroposterior distance between retruded contact and intercuspal positions of the mandible and the vertical movement of the hyoid bone between these positions.

Ingervall in 1970 in another study compared the hyoid bone positions when the mandible is in intercuspal position and when it is in postural position. He found that the hyoid bone was higher in postural position than in intercuspal position.

Nahoum HI [23] in 1971 in his study stated most malocclusions have a vertical component as well as an antero-posterior malrelationship. Information about the vertical balance of the face is extremely useful in diagnosis and treatment planning, as most experienced clinicians agree that malocclusions with marked vertical facial imbalance are generally more difficult to treat than the primarily anteroposterior discrepancies. The importance of this plane becomes apparent when we consider the fact that the palate separates the nasal and oral spaces. These spaces are two adjacent functionally related but independent functional matrices. It is possible, that the development of the spatial volumes of the oral and nasal cavities has an etiologic effect on the development of open-bite. A very important consideration is the fact that the skeletal tissues respond to the demands of the soft tissues and other factors and that the roentgenograms merely convey to us the effects of these functions.

Harvold E, et al. in 1972 in their classical experiments designed to alter the tonus of the muscles involved in the posture of the mandible by tactile stimuli to the tongue. It has been assumed that repeated tactile stimulation of the tongue will increase the tonus of the muscles lowering the mandible and eventually cause a change in postural position. To prove or disprove this assumption, following hypothesis was formulated and tested: A lowering of the postural position of the mandible will effect increased tooth extrusion and an increase in face height. A significantly larger increase in face height in the experimental animals would mean acceptance of the hypothesis. An increase in freeway space without an increase in facial height would mean rejection of the hypothesis. A lasting change in postural position would depend on migration of certain muscle attachments or increased growth in length of some muscles or a combination of the two factors. They found no significant intrapair differences at the start of the experiment. After 6 months, statistically significant intrapair differences had developed in the ratio between face height and mandibular length in both the male and female groups. The intrapair differences in monthly increase in face height also changed significantly in all of the three subgroups tested. The average monthly induced increase in face height was practically the same in all subgroups, namely, 0.55+0.05 mm.

Handelman CS & Osborne G [24] in 1976 studied the dimensions of the nasopharynx in a longitudinal sample from one to eighteen years. Quantification allowed plotting distinctive growth patterns of the bony nasopharynx, the adenoids, as well as airway capacity. The evolving facial pattern was related to the evolving nasopharyngeal pattern to identify possible relationships. All measurements were derived from lateral cephalometric films. Three nasopharyngeal variables were derived using these reference lines: nasopharyngeal depth (d), nasopharyngeal height (h) and sphenoid line palatal line angle. The nasopharyngeal area (Np area) can be subdivided into nasopharyngeal airway area and adenoid pharyngeal wall area (Ad area). The nasopharyngeal area was derived mathematically using nasopharyngeal depth (d), nasopharyngeal height (h) and sphenoid line palatal line angle. For purpose of mathematical analysis the trapezoid can be divide into a right triangle and a rectangle. Using d, h, and angle θ the Np area is defined as Np area = d (h-dtan θ)/2. The Ad area was derived by subtracting nasopharyngeal airway area from nasopharyngeal area. To conclude the trapezoid analysis proved to be usefull technique in quantification of nasopharyngeal area. The growth of the nasopharynx from nine months to eighteen years was established and reflected the different growth patterns in both males and females. The increase in nasopharyngeal area corresponds to the descent of the palate from sphenoid bone which increased nasopharyngeal height.

Graber LW [25] in 1978 stated that the hyoid bone supported by its muscular and ligamentous attachments has broader physiological ramifications as it provides a functional interface between mandibular, functional and cranial structures. Slight variations in head position in the cephalostat, the postural position of the spine, and the state of function (rest or swallow) all affect the position of the hyoid bone. However, he also pointed out that even with these limitations definite conclusions concerning the normal hyoid position may be made.

Opdebeeck, et al. in 1978 demonstrated that many of the characteristics of the Long Face Syndrome (LFS) group and the Short Face Syndrome (SFS) group can be explained by clockwise or counter clockwise rotation of the mandible " in concert " with the hyoid, tongue, pharynx, and cervical spine. The LFS group was characterized by a clockwise rotation of the mandible "in concert" with the hyoid, tongue, pharynx, and cervical spine. The mandible of the SFS group rotated similarly, but in the opposite counter clockwise direction. The vital need to maintain patency of the upper airway at the level of the base of the tongue may account for rotation in the LFS.

Woodside DG & Linder Aronson S in 1979 studied the upper and lower face heights of 120 males with complete longitudinal records at the ages 6 to 20 years (obtained from the Burlington Growth Centre, Toronto, Canada). Population standards were established on a percentile basis using data available from the total sample. Percentile plottings were made at 6, 9, 12, 14, 16, 18 and 20 years. Individual growth curves were compared to percentile population curves and the channelization of the upper and lower face height was assessed. In 22 cases with high or increasing lower face height, the size of the airway through the nasopharynx and the nose was assessed on profile and postero-anterior cephalograms respectively. Correlation analyses were carried out for the upper and lower face height and different facial variables. The variances of upper and lower face height were compared. Both the upper and lower face height did not channelize in many cases, in the majority of the cases with increasing lower face height the airway through the nasopharynx and/or the nose was narrow. No correlation was found between upper and lower face height. The variance in the lower face height was three times that of the upper face height. The upper and lower face height are highly independent variables. The lower face height is a highly independent variable with greater variance in dimension than the length of the maxilla and the mandible. The dimension of the lower face height seems to be more dependent on muscle function, environmental factors interfering with the airway and the posture of the head.

Holmberg H & Linder Aronson S [26] in 1979 carried out an investigation to clarify the value of lateral skull and frontal radiographs as a means of evaluating nasal respiratory function. The study material consisted of 162 children between the ages of 6 and 12 years, with a sex distribution of 40 percent female and 60 percent male. The capacity of the nasal airway was both measured and subjectively evaluated, using lateral skull radiographs of twenty eight children between the ages of 8 and 12 years without adenoid vegetations at the posterior nasopharyngeal wall. The size of the adenoids was measured and evaluated in a similar fashion. In addition, they were graded clinically by posterior rhinoscopy. The nasal airflow was measured according to a method previously described by Aschan and associates and subsequently modified by Linder-Aronson. In this way, simultaneous recordings of the airflow velocity and pressure gradient between the nasopharynx and nostrils were obtained.

Bibby RE [27] in 1981 opined that the hyoid bone is connected to the pharynx, mandible and cranium through muscles and ligaments. It is the only bone of the body that has no bony articulations. To minimize the variability in hyoid position, he related the hyoid bone to mandibular symphysis and third cervical vertebra in individuals with Class I malocclusions.

Harvold E, et al. in 1981in a classic study concluded from non-human primate studies that the lowering of the mandible for oral respiration was followed by a downward displacement of the maxilla and also by an increased extrusion of the teeth. The respiratory drive may initially cause the mandible to assume a lower position. The subsequent downward maxillary displacement and tooth extrusion would limit mandibular movements in an upward direction, both physically and by proprioceptive sensory input, particularly in the periodontal system. A nasal breather may change to a mouth breather because of an obstruction in the nasal or pharyngeal airway.

McNamara JA [28] in 1984 measured upper pharyngeal width as the shortest distance between posterior pharyngeal wall and a point located at the upper surface of soft palate (in its anterior half) to evaluate superior part of pharynx in lateral cephalogram. Apparent airway obstruction, as indicated by an opening of 5 mm or less in the upper pharyngeal measurement, can be used only as an indicator of possible airway impairment. In the Ann Arbor sample, the average upper airway measurement for adults of both sexes is 17.4 mm. This measurement was found to increase with age. Lower pharyngeal width was measured from the intersection of the posterior border of the tongue and the inferior border of the mandible to the closest point on the posterior pharyngeal wall. According to the measures derived from the Ann Arbor sample the average value for this measurement is 10 to12 mm and does not change appreciably with age.

Kerr WJ in 1985 studied the following relationships of nasopharyngeal dimensions – Correlation between nasopharyngeal dimensions and overbite and face height in a random male sample of non-mouth breathers. Comparisons of nasopharyngeal dimensions in Class I and Class II occlusion groups. The study sample consisted of 44 consecutive male growth study subjects with lateral cephalometric radiographs available at approximately 5, 10 and 15 years of age.

- In lateral cephalometric films of a group of male subjects, none of whom was a mouth breather, the statistical relationships were found between overbite and nasopharyngeal dimensions. Strongest correlations, with a peak at 10 years, were between:-
  a) Face height and nasopharyngeal height (+)
  b) Face height and nasopharyngeal area (+)
  c) Face height and roof angle (-)
- Dynamic correlation between overbite, face height and nasopharyngeal dimensions were weak.
- Class II malocclusion subjects on average showed:-
  a) Smaller nasopharyngeal and adenoid areas.
  b) Larger airways in both real and proportional terms compared with class I and normal occlusion subjects.

Bishara SE & Jacobsen JR in 1985 described and compared the dentofacial relationships of three normal facial types (long, average and short). Comparisons of the absolute and incremental changes between 5 years and 25.5 years of age were made both longitudinally and cross-sectionally. The subjects consisted of 20 males and 15 females for whom complete sets of data were available for the period of this study. All subjects had clinically acceptable occlusion and had not undergone previous orthodontic treatment. Descriptive statistics summarized the changes in 48 parameters, including that of height for males and females at 5, 10, 15, and 25.5 years of age. Longitudinal comparisons of the growth curves evaluated the curve profiles and curve magnitudes for the three facial types for both males and females. The analysis of variance was also used to compare the absolute and incremental changes at ages 5, 10, 15 and 25.5 years. The investigation resulted in the following findings. (1) Most persons (77%) have been categorized as having the same facial type at 5 and at 25.5 years of age. There is a strong tendency to maintain the original facial type with age. (2) Comparisons of the growth curves of the different parameters – with the exception of the incremental curves for MP:SN and Pog:NB in males, consistently demonstrated parallelism of the curves, regardless of the facial type. On the other hand, comparisons of curve magnitude indicated significant differences among the three facial types. (3) The persons within each facial type expressed a relatively large variation in the size and relationships of the various dentofacial structures. (4) Significant differences in the dentofacial parameters were present between males and females with the same facial type. The differences among facial types were not identical in males and females. (5) Longitudinal analysis of the data lends more consistent and therefore more meaningful results than cross-sectional comparisons when facial growth trends need to be evaluated.

Solow B, et al. [29] in 1986 studied the three sets of associations in a single group of nonpathologic subjects with no history of airway obstruction. Cephalometric radiographs taken in the natural head position and rhinomanometric recordings were obtained from twenty-four children, 7 to 9 years of age. Correlations were calculated between twenty-seven morphologic, eight postural and two airway variables. A large craniocervical angle was seen in connection with small mandible dimensions, mandibular retrognathism and a large mandibular inclination.

Obstructed nasopharyngeal airway (defined as a small pm-ad 2 radiographic distance and a large nasal respiratory resistance [NRR], determined rhinomanometrically) was seen on average, in connection with a large craniocervical angle, small mandibular dimensions, mandibular retrognathism, a large mandibular inclination and retroclination of the upper incisors. The observed correlations were in agreement with the predicted pattern of associations between craniofacial morphology, craniocervical angulation and airway resistance, thus suggesting the simultaneous presence of such associations in the sample of non-pathologic subjects with no history of airway obstruction. In conclusion, he stated that in this study of normal children with no symptoms of upper airway obstruction, predicted associations were found between craniofacial morphology, craniocervical angulation, and upper airway adequacy. The correlations were moderate but indicate the presence of a general control mechanism in craniofacial development.

Alan, et al. [30] in 1986 determined the relationship between pharyngeal airway and tongue structures and found that the tongue volume increases rapidly than pharyngeal airway in patients who are obese. They also found that the tongue volume increased rapidly than pharyngeal airway in patients with OSA. Alan, et al. in 1986 found the relation of craniofacial structures, tongue, hyoid bone and pharyngeal airway to OSA. The interaction was quantified by means of a canonical correlation analysis. The subjects with sleep apnoea demonstrated several alterations in craniofacial form that may reduce the upper airway dimensions and thus impair upper airway stability.

Alan, et al. in 1986 gave cephalometric & computed tomographic predictors of OSA. They demonstrated that there is cessation of respiratory efforts in Obstructive Sleep Apnoea, the effort is simply rendered ineffective by the obstruction and it is in this condition that Orthodontist may best participate in curing the symptoms.

Earle F Cote [10] in 1988 gave the description of OSA and its ramifications, with a case report on diagnosis and treatment plan and found that it could be relieved by orthognathic surgeries and with orthodontic treatment as well. He also mentioned weight reduction in obese patients who suffer from OSA as the best non-surgical treatment option.

Cheng MC, et al. in 1988 studied the anatomic and functional interrelationships associated with impaired breathing, varied neuromuscular activities and facial pattern variations.
The following two objectives are specifically addressed:

a) To determine whether characteristic combinations of morphologic and occlusal features characterize those individuals who develop facial dysplasia as compared with controls.
b) To test a hypothesis that specific types of malocclusions found in subjects with nasal obstruction relate to certain intrinsic morphologic combinations. The breathing impaired sample comprised 41 male and 30 female subjects, 15 of whom were Black and 56 Caucasian. The mean age was 11.1 years in breathing impaired subjects. This study characterized craniofacial morphology and occlusalpatterns in breathing impaired subjects and it was concluded that craniofacial morphology and occlusal patterns in the breathing impaired samples are significantly different from those in control group. The more narrow and facial widths contribute to the long-face appearance of the mouth breathers. The more dolichocephalic the head form, the more leptoprosopic is the face, with longer nasal and mandibular whole lengths, and longer facial and dentoalveolar heights.

Behlfelt K, et al. [31] in 1990 had done a study to analyse whether there were any differences between children with and without enlarged tonsils with regard to the posture of the head, the hyoid bone and the tongue. Twenty two children with enlarged tonsils were compared with a matched normal control group. Of the children in the tonsil group, 59% were mouth-breathers during the day and 82% during the night. None of the control children was a mouth-breather. The results showed that compared with the control children, children with enlarged tonsils had an extended posture of the head, a lowered position of the hyoid bone, and antero-inferior posture of the tongue. The vertical position of the hyoid bone also reflected the vertical position of the tongue. The anteroposterior position of the tongue was closely related to the oropharyngeal depth. The postural pattern in children with enlarged tonsils appears to be associated with the need for maintenance of free oropharyngeal airway capacity.

Shepard JW, et al. [32] in 1991 long before neurologists and pulmonary specialists recognized obstructive sleep apnoea (OSA) in adults. Orthodontists and otolaryngologists utilized cephalometric roentgenograms to study the relationships between breathing and craniofacial development in children. It is important to recognize that the largest increments in craniofacial growth occur within the first 4 yr of life and that craniofacial skeletal development is 90% complete by 12 yr of age. This review summarizes and updates information on a variety of investigational techniques ranging from simple visual inspection to technologically sophisticated imaging modalities that have been used to evaluate the structural and functional properties of the upper airway (UA) and were presented at two symposia. The first, entitled “Physiological Assessment of the Upper Airway,” which was held during the May 1989 Annual Meeting of the American Thoracic Society, and the second, entitled “Imaging of the Upper Airway,” was held during the June 1990 Annual Meeting of the Association of Professional Sleep Societies. Cephalometric roentgenograms have been primarily used to evaluate the skeletal and, to a lesser extent, the soft tissue anatomy that defines the boundaries of the upper airway in patients with OSA. Cephalometric roentgenograms are taken in a standardized position with the subject seated upright, teeth opposed and eyes directed forward in a natural head position so that the gaze is parallel to the floor. Roentgenographic exposures are usually made at end-inspiration. Specific cephalometric landmarks are identified with distances between these points and angles between carefully defined planes determined.

Tourne LPM in 1991 comprehensively described the growth of the pharynx and its physiological implications. According to him pharynx increases its capacity predominantly by a vertical expansion which is influenced by direction of growth at spheno-occipital synchondrosis at cervical vertebrae. He was of the opinion that dolicocephalic somatotype is characterised by more shallow pharyngeal depth and longer neck that is acquired by considerable vertical growth with downward movement of hyoid bone. He also stated that adult nasopharyngeal depth dimensions are established very early in life. The saggital stability at oropharyngeal level is influenced by the constant position of hyoid bone relative to cervical column. Adenoid vegetation and tongue mass may decrease the patency of the airway inducing postural adaptation at oropharyngeal levels which includes a drop in hyoid position relative to mandible in a attempt to secure a relatively constant antero-posterior diameter, alteration in the position of mandible at rest and extension of the cervical spine. The functional adaptation may influence the existing craniofacial pattern.

Guilleminault [2] in 1991 described the upper airway resistance syndrome, expanding the definition of OSA. He found that the Patients with upper airway resistance syndrome, constitute a group whose OSA could be easily missed by the polysomnogram. Patients with UARS have arousals during sleep related to the abnormally increased work of breathing and increased upper airway resistance, yet their respiratory disturbance index (RDI), may remain normal Ioannis P, Adamidis and Spyropoulos MN51 in 1992 investigated the hyoid bone position and inclination on the cephalometric radiographs of two groups of patients exhibiting Class I and Class III malocclusions. The radiographs were taken in both centric occlusion and wide-opened mandibular position: 17 measurements were performed on both tracings. The findings reveal a statistically significant difference in the position and inclination of the hyoid bone in the two groups. Class III patients, especially the boys, showed a more anterior position of the hyoid bone and also a reverse inclination. This might have an implication on the function of the suprahyoid and infrahyoid muscles and thus on the direction of mandibular growth. Young T, et al. [33] reported in 1993 the first reliable estimate of the population prevalence of OSA in adults: 4% and 2% of middle-aged men and women, respectively, are sleepy and have increased obstructive sleep apnoea.

Takashi, et al. in 1995 described the effect of tongue retraining device on genioglossus muscle activity in subjects with severe obstructive sleep apnoea by conducting two overnight sleep studies carried out with two TRDs, one with bulb (TRD-A) and one without bulb (TRD-B).Fluctuating GG EMG activity was found when no bulb was used however AH Index reduced with both TRDs.

Miles, et al. [34] in 1996 gave the relevance of craniofacial structures to obstructive sleep apnoea as equivocal association, quantitatively as well as qualitatively. They advocated the need of further standardization for establishing valid definitions for normal sleep, sleep disordered breathing and obstructive sleep apnoea syndrome.

Nonglok, et al. in 1996 gave some specific characteristics of craniofacial structure in Obstructive Sleep Apnoea patients by cephalometric assessment. They gave CIS (craniofacial index score) from cephalometric and anthropometric measurements to differentiate habitual snorers with and without habits. CIS can be used as effective tool to plan a treatment in OSA patients.

Pae, et al. [35] in 1997 described the role of pharyngeal length in Sleep Apnoea subjects. Narrow pharyngeal airway was found to be one of the most significant predisposing factors in OSA. Thus accordingly the treatment modalities are focussed on widening the constricted part of pharynx. They also documented that the pharyngeal length in the more supine position is important than a one-dimentional measurement of the most constricted area in the diagnosis and treatment plan of OSA.

Mark, et al. in 1997 compared two dental devices for correction of Obstructive Sleep Apnoea. They evaluated the effectiveness of these two intra-oral devices in reducing the Respiratory Disturbance Index (RDI) and Epworth Sleepiness Scale (ESS). They concluded that a dental device that advances mandible and increases the vertical dimention to open the upper airway is more effective in reducing the number of apnoeic and snoring events during sleep than one which does not advance mandible.

Joseph AA, et al. [36] in 1998 compared the dimensions of the nasopharynx, oropharynx, and hypopharynx of persons with hyperdivergent and normodivergent facial types and to determine whether any variation exists. Overall the hyperdivergent group had a narrower anteroposterior pharyngeal dimension than the normodivergent control group. This narrowing was specifically noted in the nasopharynx at the level of the hard palate and in the oropharynx at the level of the tip of the soft palate and the mandible. In addition, the posterior pharyngeal wall had a thinning at the level of the inferior border of the third cervical vertebrae and there was a more obtuse palatal angle. The tongue was also positioned more inferiorly and posteriorly in the hyperdivergent group as evidenced by the increased distance between the hyoid bone and the mandibular plane and the increased distance between the soft palate tip and the epiglottis. The hyperdivergent group had more retruded maxillary and mandibular apical bases and a higher Class II skeletal discrepancy.

Lars Bondemark [37] in 1999 studied the two year nocturnal treatment with Mandibular advancement splint in patients with snoring and obstructive sleep apnoea syndrome with respect to possible development of a forward position of mandible or other dentofacial changes. It was concluded that the change in mandibular position might result in condylar or glenoid fossa remodelling as we as change in the condylar position within the fossa as a compensatory reaction to the advancement of the mandible. To visualise and analyse these changes Lateral Tomography of the temporomandibular jointer Magnetic resonance investigation (MRI) are required.

Liu, et al. [38] in 2000 studied the effect of mandibular repositioner devices on airway, sleep and respiratory variables in patients with OSA. With these devices the retropalatal airway space increased and the crossectional area of soft palate and the vertical distances of hyoid bone to the mandibular plane decreased significantly. The tongue posture became more flatter. They found the reduction in Apnoeic episodes that was attributed to the effects of the appliance on oropharyngeal structures.

Mehra, et al. [39] in 2001 demonstrated the changes in pharyngeal airway after counter clockwise rotation of Maxillomandibular complex by Double-Jaw surgery in patients with high occlusal plane facial morphology. Double-jaw surgery was found to increase the both pharyngeal airway space and significant changes were seen in velopharyngeal anatomy as well.

Rose, et al. [40] in 2001 described the occlusal side-effects of Mandibular repositioning devices in OSA Patients and they advocated the follow-up examinations are of utmost importance if lifelong treatment of OSA was considered.

Hiyama, et al. [41] in 2001 showed the changes in pharyngeal airway in patients with OSA by studying the mandibular advancement by the use of Headgears, and whether the mandible is positioned forward during sleep with Headgears. They found that the saggital dimensions of upper pharyngeal airway were reduced. However no apperent changes were seen in vertical dimensions of the airway.

Gavish, et al. in 2001 illustrated the effect of functional magnetic system on Obstructive Sleep Apnoea. They gave two hypotheses, whether the functional magnetic increase the oral cavity airway passage or they increase the pharyngeal space. It was concluded that the functional magnets increase the anterior region of the oral cavity mainly vertically with no change in posterior oral cavity airway space or pharyngeal airway space.

Liu, et al. in 2001 illustrated cephalometric and physiologic predictors for efficacy of an adjustable oral appliance for treating OSA.A stepwise regression analysis revealed better treatment response but the patients who were younger with small dimensions of upper airway, had low body mass index, longer maxilla, smaller overjet, less erupted maxillary molars, and a large ratio of vertical airway length to the crossectional area of soft palate.

Lieberman DE, et al. in 2001 this study tested the hypothesis that spatial constraints related to deglutition impose greater restrictions on the rate and degree of hyo-laryngeal descent than do adaptations for vocalization. Ontogenetic data on changes in the size and shape of the pharynx, the vocal tract and the spatial positions of the larynx, hyoid, mandible and hard palate relative to each other and to the oral cavity were obtained for 15 males and 13 females from a longitudinal series of lateral radiographs (the Denver Growth Study) taken between the ages of 1 month and 14 years. To establish growth patterns, nine linear dimensions of the pharynx and 15 different pharyngeal and vocal-tract proportions were regressed against percentage growth. The results demonstrated that certain aspects of vocal-tract shape change markedly during ontogeny, especially in the first postnatal year and during the adolescent growth spurt. In contrast, regression analyses indicated that superoinferior spatial relations between the positions of the vocal folds, the hyoid body, the mandible and the hard palate do not change significantly throughout the entire postnatal growth period. Sexual dimorphism in pharyngeal shape and size before the age of 14 years is very limited. The results suggested that the descent of the hyoid and larynx relative to the mandible is constrained by muscle function related to deglutition, highlighting the different functional roles of the hyoid during speech and oral transport.

Tsai HH [42] in 2002 investigated the developmental changes of the hyoid bone position in children from deciduous dentition to early permanent dentition. There was no sexual dimorphism in hyoid bone positions. He concluded that without the hyoid bone, maintaining an airway, swallowing, preventing regurgitation and maintaining the upright postural position of the head could not be controlled carefully.

Rose et al68 in 2002 investigated the long term efficacy of an Oral Appliance, The Kerwetzky activator, on the respiratory and sleep related parameters in patients with OSA. This appliance was found to be effective in treating OSA but the regular polysomnographic follow-ups were required.

Ringqvist, et al. [43] in 2003 analysed the dental and skeletal side effects of Mandibular Advancement Devices after 4 years of treatment in OSA patients. The put forth the importance of considering side effects as ael as beneficial effects of the treatment whether be it Mandibular Advancement or Uveolupalatopharyngoplasty.

Johal, et al. [1] in 2004 showed the maxillary morphology, its constriction and eitiological relation in subjects with OSA. It was found that there is no significant relation between the maxillary morphology and Obstructive Sleep Apnoea. Horiuchi, et al. [8] in 2005 gave the technique for predicting effectiveness of Oral Appliances in OSA subjects. Split-light polysomnography and esophageal pressure were recorded, and cephalometric tracings were superimposed. Logistic regression analysis revealed that the degree of anterior displacement of the mandible showed significant odd ratios. But it was concluded that evaluation based on PES and analysis of mandibular displacement expressed by vector resolution using a cephalometric superimposition technique is useful in assessing the efficacy of oral appliances in treating OSA.

De Freitas MR, et al. in 2006 compared upper and lower pharyngeal widths in patients with untreated Class I and Class II malocclusions having normal and vertical growth patterns. The sample comprised of 80 subjects divided into 2 groups: 40 Class I and 40 Class II, subdivided according to growth pattern into normal and vertical growers. The upper and lower pharyngeal airways were assessed according to McNamara's airway analysis. It was concluded that subjects with Class I and Class II malocclusions and vertical growth patterns have significantly narrower upper pharyngeal airway than those with Class I and Class II malocclusions and normal growth patterns. However, malocclusion type does not influence upper pharyngeal airway width and malocclusion type and growth pattern do not influence lower pharyngeal airway width.

Martin O, et al. [44] in 2006 conducted a study to assess nasopharyngeal soft-tissue patterns in patients with ideal occlusion. A sample of 91 patients was selected; none of the subjects had a history of sleep disorder, snoring, sleep apnoea, upper airway disease, adenoidectomy or pathology in the pharynx. Lateral cephalograms were digitized and linear and area measures were made to define the airway pattern. The Student t test and the Pearson correlation analysis were applied to compare sex differences and variable correlations. A factorial data analysis was also applied to prove a group-dependant relationship between variables. Following results were drawn: Nasopharyngeal soft-tissue patterns were different in men and women. Nasal fossa, cranial base and adenoidal tissue were larger in men. All variables except lower pharynx dimensions were found to be statistically related. Great dependence was observed between some variables: upper airway thickness explained 60% of the changes in upper pharyngeal dimension and 67% of the changes in aerial area. Cranial base length was also statistically related with different variables that define the airway, mainly nasal fossa length and lower airway thickness. Nasal fossa length was statistically correlated with upper airway thickness. McNamara's lower pharyngeal dimension did not depend on other variables used in this study. Five groups of variables tended to be related among themselves but not with others. They concluded that a relationship exists between skeletal and dental anomalies and airway obstruction and possible specific respiratory patterns for each type of malocclusion.

Sung, et al. [45] in 2006 used the computerised stimulation to describe the role of fluid dynamics in upper airway of OSA patients. It was concluded that high airflow velocity predominates in medial and ventral nasal airway regions. Maximum air velocity and lowest pressure were observed at the narrowest portion of velopharynx.

Otsuka, et al. [6] in 2006 compared the responders and non-responders of oral appliances with OSA. It was seen that the middle and inferior airway space and oropharyngeal airway crossectional area were significantly larger in the non-responders. Position of the mandible relative to cervical spine was the only significant skeletal variable and was larger in non-responders. The wider airway in non-responders was supposed to reflect as enhanced neuromuscular compensation while awake. The weight gain in nonresponders was relatively small, but it might reduce the effectiveness of oral appliance.

Hammond, et al. [46] in 2007 illustrated the dental and skeletal changes as wel as the side effects of Mandibular Advancement Splint in OSA subjects. The most common side effects were discomfort, tooth tenderness, excessive salivation and dry mouth. And in the same year treatment of OSA patients with Mandibular Distraction Osteogenesis was documented. It was found that the treatment lasted for 3 years and 1 month. An acceptable occlusion was obtained but Condylar resorption was observed.

Jayan B, et al. [47] in 2007 based on linear and angular measurements, compared cephalometric data of 28 Urban Indian Obese (Group I) and 15 urban Indian non obese (Group II) Polysomnography (PSG) diagnosed Obstructive sleep apnoea (OSA) adult with 20 age-sex matched controls (GroupIII). Co–relation of cephalometric variables with Apnoea Hypopnoea index (AHI) was also evaluated and suitable statistical tests applied. In Group I, Cephalometric measurements; PAS (Posterior airway space), PNS-P (Length of soft palate), MPH (Hyoid distance) were found to be highly significant ($p<0.01$) and G (Width of soft palate) was found to be significant ($p<0.05$). In Group II, Cephalometric measurements; PAS, PNS-P and G were found to be highly significant ($p<0.01$), while SNB (relationship of mandible to cranial base), MPH, were found to be statistically significant ($p<0.05$). Positive correlation ($p<0.05$, $r^2 = 0.163$) was observed between MPH and AHI. No significant correlation was observed in other cephalometric variables with AHI in Group I and Group II. They concluded that predictable cephalometric measurements in OSA patients combined with PSG findings can be employed effectively for diagnosis and treatment planning in our settings. They concluded that predictable cephalometric measurements in OSA patients combined with PSG findings can be employed effectively for diagnosis and treatment planning in our settings.

Chen, et al. [48] in 2008 performed three dimensional computer assisted study model to illustrate the effects of long-term use of oral appliances. It was seen that mandibular arch width increased more than maxillary arch width, crowding decreased in both the arches and curve of Spee decreased in the premolar area, mandibular canine to second molar segment moved forward in relation to maxillary arch.

Pae EK, [49] in 2008 studied lateral head radiographs of men with the following hypothesis:

1) The hyoid bone moves inferiorly over time,
2) There is a proportional relationship between hyoid descent and age and
3) The extent of hyoid descent might vary depending on facial types.

This study was performed with special focus on the vertical changes in hyoid bone position. Unlike previous cephalometric studies, this analysis mainly focused on the relationship of hyoid position and changes in this position to subject's age, obesity (body mass index [BMI], ratio of weight in kilograms to height in meters) and facial type. Pairs of lateral cephalometric radiographs taken 15 years apart to assess vertical changes over time in hyoid position in 163 normal white men (30-72 years) were used. Four linear distances that reflected hyoid position were selected: hyoidale to sella (HYS), hyoidale to mandibular plane perpendicular (HYMP), hyoidale to retrognathion (HYRGN) and hyoid angle measured from gonion to hyoidale to menton (GOHYME). To evaluate length and width changes of the oropharynx, the linear distance between posterior nasal spine and the base of the epiglottis (PNSV) and the distance between the posterior pharyngeal wall and the dorsal surface of the tongue (IAS) were measured. The FMA or mandibular plane angle was used to divide the facial types into groups. The traditional terms for the 3 basic facial types are dolichofacial (hyperdivergent), mesofacial (normal), and brachyfacial (hypodivergent).

The authors made the following pertinent conclusion:

1) Hyoid position changes appear to continue lifelong and are associated with aging.
2) Hyoid position and changes are independent of obesity.
3) Hyoid position and changes differ by facial types; thus facial forms should be considered for appropriate comparison.

Sheng CM, et al. [50] in 2009 conducted a cross-sectional study with the following objectives:

(1) To investigate changes in the pharyngeal airway depth and hyoid bone position during development from the early mixed dentition to young adulthood in normal Taiwanese persons.
(2) To identify any sexual dimorphism in these developmental changes,
(3) To evaluate the predictive value of selective variables for the hyoid bone position. Lateral cephalometric radiographs of 239 Taiwanese subjects (132) females and 107 males), aged 7 to 27 years were reviewed.

The materials were divided into three stages according to dental age: mixed dentition (stage 1), early permanent dentition (stage 2) and complete permanent dentition (stage 3). Following conclusions were made: Developmental changes occur in the pharyngeal airway depth and hyoid position from childhood to young adulthood. Sexual dimorphism appeared in the lower pharyngeal airway and the direction of change in the vertical position of the hyoid bone. The findings might shed some light on the reason why some breathing disorders are male predominant.

Yow M [51] in 2009 described the use of oral appliances and management of airway in patients with OSA. It was concluded that n-CPAP nadoaral appliances therapy were effective in reducing subjective daytime sleepiness, However there was no improvements found in wakefulness test in both n-CPAP and Oral Appliances.

Sittitawornwong, et al. [52] in 2009 evaluated OSA Syndrome by computational fluid dynamics. It was done to evaluate the anatomical changes in OSA patients who were treated with Maxillomandibular Advancement with 3D Geometric reconstruction and computational fluid dynamics. It was found that the MMA surgeries reduce the airway resistance and pressure effort of OSAS by increasing the dimension of the airway. Tsai in 2009 demonstrated whether there exists some association between genders differences in Anthropometric an Cephalometric characteristics and the severity of OSA Syndrome. The craniofacial skeletal characteristic that was found to contribute to OSAS was in the anterior lower portion of the profile in men and in the posterior portion of the profile in females.

Jena AK, et al. [53] in 2010 evaluated the pharyngeal airway passage dimensions among subjects with normal, retrognathic and prognathic mandibles who demonstrated a similar vertical growth pattern of the mandible. Pre-treatment lateral cephalograms of 91 North Indian subjects aged 15–25 years with a normal vertical growth pattern of the mandible were selected for the study. They had a normal position of the maxilla (angle SNA 79°– 83°) with various stages of sagittal mandibular development in relation to the anterior cranial base. Group I included 37subjects who had a normally positioned mandible in relation to the anterior cranial base (SNB< 82°), Group II included 31 subjects in whom the mandible was retrognathic (SNB<76°), and Group III included 23 subjects in whom the mandible was prognathic (SNB >82°) in relation to the anterior cranial base. Lateral cephalograms were traced manually to evaluate the pharyngeal airway passage.

Following conclusions were inferred from the study:–

a) Sagittal mandibular development had significant effects on the dimensions of the awake pharyngeal airway passage.
b) The length of the soft palate was smaller among subjects with mandibular prognathism than among subjects with normal and retrognathic mandibles.
c) The thickness of the soft palate was greater among mandibular prognathic subjects than among subjects with normal and retrognathic mandibles.
d) Sagittal mandibular development had a significant influence on the inclination of the soft palate.
e) The dimensions of the nasopharynx and hypopharynx were independent of sagittal mandibular development.
f) The depth of the oropharynx was greater among subjects with mandibular prognathism than among subjects with normal and retrognathic mandibles.

Zhong Z, et al. [54] in (2010 studied upper airway dimensions among Chinese nonsnoring children of different sagittal and vertical skeletal facial morphologies. Lateral cephalometric records were used to measure the dimensions of the upper airway. Two groups of subjects were studied. A group of subjects with a normodivergent facial pattern (FH-MP angle between 23.5° and 30.5°) was divided into three subgroups according to ANB angle (Class I, II, or III). A second group of subjects with a normal sagittal facial pattern (ANB angle between 0.7°and 4.7°) was divided into three subgroups according to the FH-MP angle (low angle, normal angle or high angle). All subgroups were matched for age and sex. Results obtained from this study were: In the group of subjects with a normodivergent facial pattern, a significant tendency for reduced upper airway dimension in the inferior part (palatopharyngeal and hypopharynx) was found in the Class III, Class I and Class II subgroups, in that order. In the group of subjects with a normal sagittal facial pattern, the superior part of the airway (nasopharyngeal and palatopharyngeal) decreased with increasing mandibular plane angle. It was concluded that sagittal and vertical skeletal patterns may be contributory factors for the variation of the inferior and superior part of the upper airway, respectively. Skeletal deficiency of nonsnoring Chinese children may predispose them to upper airway obstruction.

Goncalves RC, et al. [55] in 2011 reported a retrospective study which evaluated the influence of age and gender on upper and lower airway width and upper lip length. In this study 390 lateral cephalograms were divided into 13 age groups (ranging from 6 to 18 years) and were analyzed. The intergroup differences were analyzed using a MANOVA (Multivariate Analysis of the Variance), and the intra group differences were analyzed using an ANOVA (Analysis of the Variance) and Turkey's test. The results of the present study indicated that although the airway width and the upper lip length increased with age, the lower airway width exhibited variable growth between the ages of six and eighteen years. The airway width was significantly greater in females than males, whereas the upper airway width was similar between these two genders. The lower airway width and upper lip length were significantly different between males and females, whereas the upper airway width was similar for the genders. The upper airway width and upper lip exhibited incremental growth between the ages of six and eighteen years. The upper lip closely followed the growth pattern of the upper airway width; the growth plateaued between the ages of 6 and 9 years, increased from 9 to 16 years and plateaued from 16 to 18 years.

Jena AK & Duggal R [56] in 2011in their retrospective study analysed hyoid bone position among subjects with different vertical jaw dysplasias. Seventy-one North Indian adult male and female subjects in the age range of 15 to 25 years were selected for the study. Based on the vertical growth pattern of the face, subjects were divided into Group I (n = 24; subjects in whom both Frankfort mandibular plane angle [FMA] and basal plane angle measured 20 to 25 degrees), Group II (n=17; subjects in whom both FMA and basal plane angle measured <15 degrees), and Group III (n=30; subjects in whom both FMA and basal plane angle measured >30 degrees). Lateral cephalograms with the mandible in rest position were traced and analyzed manually for evaluation of hyoid bone position. The study found that the anteroposterior position of the hyoid bone was more forward in subjects with short face syndrome and the vertical position of the hyoid bone was comparable among subjects with different vertical jaw dysplasias. Axial inclination of the hyoid bone closely followed the axial inclination of the mandible.

Ucara FI & Uysal T [57] in 2011evaluated orofacial airway dimensions in subjects with Class I malocclusion and different growth patterns. Lateral cephalometric radiographs of 31 low angle (mean age, 14.06± 2.0 years), 40 high angle (mean age, 12.7±6 years), and 33 normal growth (mean age, 13.9±3 years) subjects with Class I malocclusion were examined. In total, 34 measurements (27 craniofacial and 7 orofacial airways) were evaluated. Groups were constituted according to the SN-MP angle. They concluded from their study that statistically significant differences were identified in most of the craniofacial measurements among Class I subjects with three different vertical growth patterns.

Nasopharyngeal airway space and upper PAS in Class I subjects were found to be larger in low angle subjects than in high angle subjects. Palatal tongue space and tongue gap were larger in high angle subjects than in low angle subjects. Tongue gap was statistically greater in high angle than in normal angle subjects.

Khanna R, et al. [58] in 2011 reported a study in which pharyngeal dimensions in Angle's Class I normal and Angle's Class II division1 samples were compared and correlated with dentoskeletal parameters. It was based on lateral cephalograms of 92 individuals selected on the conviction that they should present Angle's Class I and Angle's Class II molar relationship. The cephalograms of the subjects were categorized into the following two groups. 1) Group A: Subjects having Angle's Class I molar relationship with ideal occlusion and no significant abnormalities in the vertical dimension of facial form. This group comprised of 25 male and 21 female subjects. 2) Group B: subjects having Angle's Class II division 1malocclusion. This group comprised of 25 male and 21 female subjects from the patients reporting at the Department of Orthodontics, King George's Medical College, Lucknow. The subjects of entire sample mentioned above fell in the age group of 16 to 24 years, with the mean age of 18 years for females and 20 years for males. Total five linear and seven angular measurements were analyzed:
The following conclusions were drawn:

a) Angle's Class II division 1 samples with retrognathic mandible showed an inferoposterior displacement of hyoid bone.
b) The positional alteration of hyoid was prevalent in skeletal malrelationship rather than dentoalveolar malocclusion.
c) The anteroposterior dimension of pharynx at hyoid level was more in males than in females and it was relatively less in Angle's Class II division 1 samples when compared with Class I samples.
d) No significant sexual dimorphism exists in angular measurements of hyoid positioning.

Huynh, et al. [59] in 2011 demonestrated the association between sleep disordered breathing and facial and skeletal morphometry with screening examination. They reported that the early intervention of snoring in Pediatric Patients can be helpful in preventing OSAS. In contrast to sleep disordered breathing or Sleep Apnoea in Adults, which is predominantly associated with obesity, sleep-disordered breathing symptoms in the Pediatric cohort were primarily associated with adenotonsilar hypertrophy, morphologic features related to a long and narrow face and allergies.

Ngiam, et al. [60] in 2012 performed microimplant assisted mandibular advancement therapy for treating snoring and Obstructive Sleep Apnoea. Highly significant reduction in Apnoea-Hypopnoea, snoring and Sleep variables were observed which highlight the potential of microimplant based mandibular advancement therapy as an alternative treatment modality for OSA patients who cannot tolerate Continuous Positive Air Pressure and Oral Appliances.

Jacobson, et al. [61] in 2012 illustrated surgical procedures as treatment modality in correction of OSA and concluded that the surgery play an important role in treating OSA and is the treatment of choice even in the mild to moderate cases of OSA. They also suggested that a surgeon should always work with the Orthodontist trained in Sleep Medicine, since their combined treatment expertise, optimally exercised, yields superior short-term and long-term results.

Katyal V, et al. [62] in 2013 described craniofacial disharmony and upper airway morphology in Pediatric sleep disordered breathing. Children with OSA were found to have increased ANB due to decreased SNB but the direct association was not found of this increased ANB to OSA by Meta Analysis. There is a strong support for reduced upper airway width in children with OSA.

Ling Ma, et al. [63] in 2013 gave the association between resting jaw muscle electromyographic activity and mandibular advancement splint outcome in patients with OSA in two groups. The groups were divided as responders and non-responders. Baseline differences in muscle activity in these two groups to Mandibular Advancement Splint treatment were observed. They suggested that there might be a correlation between responsiveness with Mandibular Advancement Splint and baseline muscle activity.

Chang, et al. in 2013 described dimensional changes of upper airway after rapid maxillary expansion. It was found that the only the crossectional area of the upper airway at the posterior nasal spine to basion level significantly gains a moderate increase after Rapid Maxillary Expansion.

Katyal V, et al. [64] in 2013 reported a systematic review and metanalysis on craniofacial and upper airway morphology in paediatric sleep disordered breathing.
The following conclusions were drawn by them:

1) There is statistical support for an association between craniofacial disharmony and paediatric sleep disordered breathing.
2) Increased ANB angle of less than 2° in children with OSA and primary snoring compared with controls had marginal clinical significance.
3) Evidence for direct causal relationship between craniofacial structure and paediatric sleep disordered breathing was unsupported by the metanalysis.

Fastuca, et al. [65] in 2014 described the role of mandibular advancement after rapid maxillary expansion in subjects with OSA and found that no significant differences were evident regarding oropharyngeal airway changes and mandibular displacement after rapid maxillary expansion.

Ghodke, et al. [66] in 2014 demonestrated the effect of Twin Block appliance in Class II Div 1 malocclusion cases with OSA. It was found that the depth of oropharynx and hypopharynx was increased significantly. It was concluded that the correction of mandibular retrusion by Twin-Block Appliance in Class II Malocclusion subjects increased pharyngeal airway space and maintained the pre-treatment thickness of posterior pharyngeal wall.

Anatomy of the Airway

The anatomy of the upper airway, including the oral cavity and mouth, begins with the intake of air through either the nose or the mouth. The critical component controlling the airway and airway function are the muscles that control airway dimension or opening and are related to the primary structures of the airway, such as the tongue, soft palate, and uvula as well as the upper and lower pharynx. Some hard tissue structures need to be considered, especially within the nose [67].

The pharyngeal airway is customarily divided into four segments: nasopharynx, velopharynx, oropharynx, and hypopharynx. Within these areas many different muscle groups work to maintain the airway and to facilitate respiration; these muscle groups may, at the same time, be used for swallowing or speech.

Nasopharynx

The nasopharynx is the uppermost portion of the airway and mainly involves the nose. It begins with the nares, where air enters the nose, and extends back to the hard palate at the superior portion of the soft palate. The structures of major concern in this segment are the nasal turbinates and nasal septum.9Theturbinates (choanae) is comprised of three paired structures: the inferior, middle, and superior turbinates. The inferior turbinates are the largest and filter air as it passes through the nose. The middle and superior turbinates humidify the air as it passes through the nose. If the inferior turbinates are enlarged, they contribute to nasal airway obstruction, which can affect breathing. Additionally, a deviated septum may affect nasal respiration.

Velopharynx

The velopharynx is also referred to as the retropalatal area. It ex tends from the hard palate to the inferior tip of the soft palate and includes the uvula and the uppermost segment of the posterior pharyngeal wall. The muscles of major concern are the tensor palatini and the levatorpalatini, both of which elevate the soft palate. The uvula contains the musculus uvulae, which elevates this structure.

Oropharynx

The oropharynx is also referred to as the retroglossal area and is comprised of the oral cavity, beginning with the back portion of the mouth and extending rearward to the base of the tongue. The major components are the tongue and the tonsils. Enlargement of either of these structures can cause airway obstruction. Muscular control of the tongue is important in maintaining an open airway. Within this area are a large number of muscles that control tongue posture as well as mandibular position; these muscles help maintain the airway and contribute to airway function. Muscles that affect mandibular movement that impact the airway include the medial and the lateral pterygoid.

Hypopharynx

The hypopharynx extends from the epiglottis to the lowest portion of the airway at the larynx. This area is the most difficult to assess for airway compromise because it can be viewed only by fiberoptic endoscopy or by sophisticated imaging techniques such as MR imaging. A large number of muscles affect this portion of the airway and can have varying effects, depending on the concurrent activity of other related muscles.

Muscular Function and Relationships

The soft palateis controlled mainly by the levatorvelipalatini and the tensor velipalatini. These muscles act to elevate and tense the soft palate. The tongue is made up of a number of muscles which are divided into two tips, the intrinsic and extrinsic. The extrinsic muscles are outside the body of the tongue and control tongue position and posture. These muscles are the genioglossus, which is a midline muscle that controls protrusion, retrusion, and depression of the tongue, the palatoglossus, hypoglossus, styloglossus, and chondroglossus.

The hyoid is a free-standing bone that is controlled by two groups of muscles, the suprahyoids and the infrahyoids. The suprahyoids are the digastric, geniohyoid, mylohyoid, and stylohyoid muscles. This group of muscles elevates the hyoid bone; however, they also can work in an antagonistic manner. In particular, the stylohyoid can move the hyoid bone posteriorly, and the geniohyoid can move it anteriorly or forward. The suprahyoid muscles may work in conjunction with the infrahyoids to stabilize the hyoid so that the muscles of the tongue and pharynx that insert on it can perform the required mechanical action.

The infrahyoid muscles are the omohyoid, sternohyoid, and thyrohyoid. These muscles act in an antagonistic fashion to the suprahyoids by moving the hyoid bone downward or inferiorly. These muscle groups' further aids in the stabilization of the hyoid complex. The posterolateral pharyngeal walls are affected by another large group of muscles. In the oropharynx the palatoglossus and palatopharyngeus are active in controlling airway dimension. The palatoglossus is contained in the anterior tonsillar pillar and acts by elevating the posterior portion of the tongue at its base. The palatopharyngeus is located in the posterior tonsillar pillar and exerts its effect by pulling the pharyngeal walls upward, forward, and medially and also doses the nasopharynx. Depicts the synergistic action of the palatopharyngeus and palatoglossus muscles as they are affected by mandibular advancement and opening vertically. As the mandible is advanced, the muscles are spread apart, causing tension on the palatoglossus. This tension is transferred to the soft palate, thus reducing vibration; hence, snoring may be eliminated or reduced by mandibular advancement. Dong has demonstrated that the force vector that is parallel to the axis of the palatoglossus muscle actually produces the tension needed to stabilize the soft palate. Huang and co-workers also demonstrated that mechanical stiffness in the upper airway helps to prevent snoring. They concluded that people who have flexible upper airways are most likely to snore. To increase the force vector with the mandible advanced, one would increase the vertical component if the mandible is opened too much; however, the tissues around the oropharynx will constrict, and the airway may then- obstruct The delicate balance maintained by the muscles of the airway can be beneficially or adversely affected by alterations in mandibular advancement and vertical changes.

Two other muscles, the stylopharyngeus and the salpingopharyngeus, act on the oropharynx. Their action is primarily during speech and swallowing; although a specific function with respiration has not been identified, they do seem to have an effect on the pharynx.

Another group of muscles that needs to be considered are the constrictor muscles of the pharynx. The middle and inferior pharyngeal constrictors stabilize the lateral and posterior walls of the airway, primarily during inspiration. Their action can fluctuate depending on the airway volume being managed.

The last group of muscles that must be considered are the muscles of the neckthat support the cervical spine. These muscles are the posterior cervicals and the suboccipitals, including the upper trapezius. Alteration in the cervical spine can modify the airway, primarily through the effect on the hyoid bone. Therefore, it is important that during the clinical aspect of the examination the posture of the individual and its potential impact on the airway be considered. This evaluation should be done with the patient standing in an upright and relaxed position to allow the examiner to determine the patient's posture when unsupported.

Rocabato has shown that the curvature of the cervical spine can have an effect on the position of the hyoid, which in turn can affect mandibular position and the airway. He has demonstrated that the altered head position can cause Class II malocclusions. This retrusion of the mandible may be involved in airway obstruction because the associated soft tissue structures, particularly the tongue, are more likely to contribute to air way obstruction.

Physiology of the Upper Airway

In healthy patients, as the chest muscles expand a negative pressure is created which draws air into the lungs. Because this negative pressure extends from within the lungs through the upper airway, the airway is under negative pressure during inspiration. When unimpeded, air passes reasonably freely through the upper airway, although there is some minor resistance to the airflow by friction against the walls of the pharynx. Along the way, the airflow and negative pressure may influence multiple anatomic structures including the dorsal surface and base of the tongue, uvula, nasal structures, lateral and posterior walls of the pharynx, adenoids, and tonsils.

The upper airway is basically a soft tissue tube, the patency of which is maintained in part by the activity of muscular groups of which the tensor veli and genioglossus muscles are highly important members.

Etiopathology of OSA

Snoring

Patients are not considered to have a severe problem when they suffer from snoring only, because snoring is mainly a problem that creates irritation and loss of sleep in their bed partners. Occasionally, when severe enough, the loudness of the snoring may awaken the patient, causing a loss of quality and quantity of sleep resulting in tiredness and sleep resulting in tiredness and sleepiness during the day.

Snoring is often the result the base of the tongue compromising the upper airway. This obstruction happens when a patient falls asleep in the supine position; with muscle relaxation, the base of the tongue in the supine position; with muscle relaxation, the base of the tongue approaches the posterior wall of the pharynx. With a reduced airflow, caused by the compromise, the patient must increase the speed of the airflow in an attempt to maintain the required oxygen to the lungs. The increase in airflow velocity often causes vibration of soft tissues. This vibration is the sound of snoring. Often, the uvula is the soft tissue vibrating, but any tissues vibrating, but any tissues that can vibrate can cause the problem. Although the tongue is often the cause of the upper airway compromise, many conditions which impinge on the airway including obesity, edema, polyps, inflamed adenoids or tonsils, or tumours, may cause the problem. Snoring in and of itself may be only a social annoyance. Because almost all patients with OSA snore, however, snoring must be considered a potential indicator of significant medical problems. Patients or more commonly their spouses are beginning to request oral appliances to treat snoring problems.

Sleep apnoea

Patients with OSA have a blockage of the upper airway that may be caused by a variety of anatomic or pathologic conditions. When many of these patients relax and fall asleep, the tongue drops back and actually contacts the posterior and lateral walls of the pharynx. In others, the tongue may not actually contact the walls of the pharynx, but when the patient attempts to inspire, the negative pressure created will suck the tongue and pharynx walls together. In either situation, the patient has an upper airway blockage that prevents air from reaching the lungs. Patients with OSA invariably exhibit severe, chronic, loud snoring.

Anatomically, a blockage occurs more easily for patients with excess fat tissue (obesity), inflamed tissues, or tumours in the upper airway.

The upper airway is basically a soft tissue tube maintained by the activity of muscular groups including the genioglosus muscles. Studies indicate that when patients with OSA relax and fall asleep, the timing of these muscles may be altered, allowing a blockage of the airway to occur.

Genes

The craniofacial complex involves the maxilla, the mandible, and mandibular growth. It is generally considered that size is probably the element that is most influenced by genes. Size is important, because it influences shape. A change in the length of the mandibular body or ramus, for example, has altering effects on the shape of the face. Changing only one dimension can alter how the other parts fit together. The direction in which growth is expressed is more influenced by the surrounding hard and soft tissues.

Familial Tendency

Sleep disordered breathing has been reported to occur in familial aggregates. In 1978, Stohl, et al. reported the association in the same family of a SIDS case and several cases of OSAS. Guilleminault, et al. [2] reported the familial association in several generations of SIDS and ALTE, with OSA in adults, and the presence of a small upper airway as determined by imaging techniques. These studies suggest an anatomic involvement in the occurrence of sleep-related upper airway occlusion in familial aggregates.

Other factors such as thickening of the pharynx walls and lengthening of the pharynx that occurs on assuming the supine position may also contribute to OSA.

Upper Airway Resistance Syndrome

Patients with UARS will go to sleep, then begin loud, crescendo snoring which leads to an arousal or awakening. This arousal is followed by the patient's falling back to sleep, resumption of snoring, and awakening again. These patients may exhibit all the clinical symptoms of OSA but without apnoeic or hypopnoeic events. Upper airway resistance syndrome is not a well-defined condition, and its diagnosis is therefore difficult. These patients are presently treated as if they had OSA.

Clinical Features

OSAHS patients have significantly more hypertension, ischemic heart disease, and cerebrovascular disease than individuals without OSAHS. However, OSAHS patients have a high incidence of other coexisting cardiovascular risk factors such as obesity, hyperlipidemia, increased age, smoking history, and excessive alcohol intake, which potentially confounds the identification of an independent association of OSAHS with cardiovascular disease.

Among other consequences of sleep apnoea, excessive daytime sleepiness (EDS), cognitive impairment, impaired ability to operate a motor vehicle and an increased automobile accident rate have been recently documented. The patients' relative risk to have an accident lies between 2.3 and 7.3 times than that of non-apnoeic individuals [68].

A series of recent studies agreed that patients with OSAHS have a reduced quality of life. There is a clear association between headache and sleep disturbances, especially headaches occurring during the night or early morning. Patients with headache also report more daytime symptoms like fatigue, tiredness, or sleepiness. These symptoms contribute to their reduced quality of life.

Sleep apnoea patients have constricted upper airways that increase the pharyngeal resistance during inspiration. This, in turn, necessitates an increase in pharyngeal dilator muscle contraction to maintain airway potency. Such an increase has been shown in OSAHS patients during wakefulness, but was also shown to decrease in contraction during sleep, thus contributing to the development of obstructive apnoea. Interestingly, when compared with normal, OSAHS patients show greater pharyngeal dilator muscle contraction during sleep, suggesting that an imbalance between negative airway pressure and dilator muscle contraction is responsible for the obstruction, rather than a primary deficiency in muscle contraction. A sustained increase in dilator muscle contraction in OSAHS could predispose these muscles to fatigue, possibly aggravating the tendency to pharyngeal occlusion Figure 3.

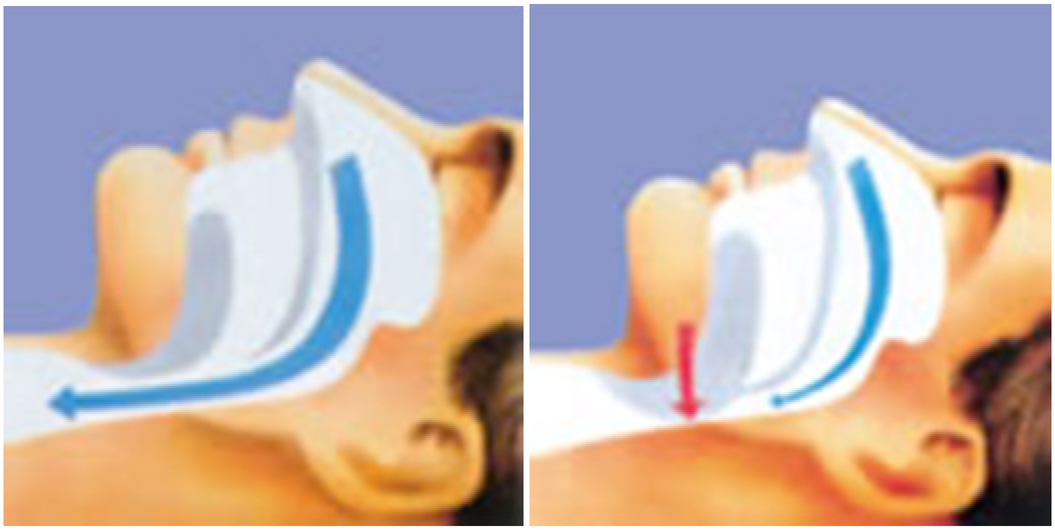

Figure 3: Features of Obstruction.

Severity Assessment

Mild OSA includes records with 5 to 15 events per hour, moderate OSA includes records with 15 to 30 events per hour, and severe OSA includes records with more than 30 events per hour.

The task force recommended the following descriptions of the clinical severity of sleepiness:

a) **Mild:** Unwanted sleepiness or involuntary sleep episodes occur during activities that require little attention. Examples include sleepiness that is likely to occur while watching television, reading, or travelling as a passenger. Symptoms produce only minor impairment of social or oSccupational function.
b) **Moderate:** Unwanted sleepiness or involuntary sleep episodes occur during activities that require some attention. Examples include uncontrolled sleepiness that is likely to occur while attending activities such as concerts, meetings, or presentations Symptoms produce moderate impairment of social or occupational function.
c) **Severe:** Unwanted sleepiness or involuntary sleep episodes occur during activities that require more active attention. Examples include uncontrolled sleepiness while eating, during conversation, walking, or driving. Symptoms a marked impairment of social or occupational function

Obstructive Sleep Apnoea Syndrome in Children and Adults

Snoring is characteristic of OSAS in children with OSAS may not have children in the presence of severe upper airway associated with observed pauses and snore, restless sleep, diaphoresis, morning thirst, nightmares, sleep terrors, frequent n are common associated symptoms. Daytime abnormalities include sleepiness, hyperactivity attention span problems, behavioural abnormalities, unusual aggressiveness, moodiness, and excessive shyness. Difficulty in learning, frequent upper airway infections, sinusitis, frequent otitis media, failure also be symptoms. In severe cases, pulmonary hypertension and cor-pulmonale can develop.

Most often, OSAS during childhood is associated with an anatomic abnormality of the upper airway. The most common anomaly is hypertrophic tonsils and adenoids. Enlargement of the pharyngeal tonsils and adenoidal tissue decreases the radius of the nasal and oral airway. The outcome is increased airway resistance. This increase may not be significant during waking hours when the child spends most time up-right but may become clinically significant at night during sleep when the youngster is lying in bed in a horizontal position. Airway resistance exceeds the critical closing pressure of the airway, resulting in collapse and occlusion.

Malformations of the mandible and maxillae can also result in upper airway obstruction during sleep. Any abnormality that decreases the radius of the nasal or oral airway can result in increased airway resistance. Bernoulli's principle and Poiseuille's law of laminar flow in a tube provide clues to the reason for airway collapse in children. Much depends upon the anatomic size of the airway.

Among children and adolescents, the prevalence of primary snoring has been reported at 3.2% to 12.1%, and the prevalence for obstructive sleep apnoea is estimated at 0.7% to 10.3%.Sleep-disordered breathing in children has been associated with a wide variety of symptoms Patients often report associated excessive daytime fatigue, morning headaches, loud and abnormal snoring or breathing, restless sleep, impaired intellectual function and attention, mood disturbance, aggressive behaviour, and hyperactivity. Sleep disordered breathing is often under diagnosed in children and teenagers because the primary complaints reported by parents are more often behavioral symptoms. Although enlarged tonsils and adenoids contribute greatly to pediatric sleep-disordered breathing, multiple anatomic obstructions should also be considered.

Although it is debated, cephalometry in children and adult obstructive sleep apnoea patients has shown that decreased mandibular and maxillary lengths, skeletal retrusion, increased mandibular plane angle, and low hyoid position have implications in sleep-disordered breathing. In the vertical plane, children with long faces, retropositioned mandibles, and associated lip incompetence have been shown to have increased sleep-disordered breathing and obstructive sleep apnoea symptoms. In the transverse plane, maxillary constriction is a sign of reduced transverse dimension of the upper airways and increased nasal resistance, which results in increased mouth breathing. Transverse maxillary deficiency can be clinically assessed, a high, narrow palate, and severe crowding of the maxilla and the mandible might also be present. In the antero posterior plane, a micrognathic or retrognathic mandible will most likely because the tongues to reduce the pharyngeal airway space and decrease air flow during sleep.

Children and adolescents seeking orthodontic treatment have some form of craniofacial disharmony. Approximately15% to 22% of children who have not yet received orthodontic treatment has occlusal asymmetry, and nearly 30% have sagittal asymmetry. In addition, nearly 18% of American children (12-17 years of age) have incisor crowding and malalignment. Therefore, the craniofacial disharmony seen in the orthodontic clinic can possibly overlap with those previously identified as risk factors for sleep-disordered breathing or obstructive sleep apnoea in children. Many studies have reported a positive relationship between craniofacial morphologic characteristics in children and sleep disordered breathing symptoms. However, these studies were done on patients who were referred to either sleep clinics or ear, nose, and throat clinics for snoring or obstructive sleep apnoea. The objective of our study was to evaluate the prevalence of sleep-disordered breathing symptoms and their associations with facial or dental morphometry in a more general setting, such as a general pediatric orthodontic population, where orthodontists are experienced in evaluating craniofacial morphology and growth [69].

Symptoms of Obstructive Sleep Apnoea in Children and Adults

Nighttime	*Daytime*
• Abnormal sleeping positions	• Morning tension-type headache
• Chronic, heavy snoring	• Mouth breathing
• Confused arousal	• Excessive morning thirst
• Delayed sleep onset	• Excessive fatigue and sleepiness
• Difficulty breathing during sleep	• Abnormal shyness, withdrawn and depressive presentation
• Difficulty waking up in the morning	• Behavioral problems
• Drooling	• Pattern of attention-deficit/ hyperactivity disorder (ADHD)
• Enuresis	• Aggressiveness
• Frequent awakenings	• Irritability
• Insomnia	• Poor concentration
• Mouth breathing	• Learning difficulties
• Nocturnal migraine	• Memory impairment
• Nocturnal sweating	• Poor academic performance
• Periodic limb movement	
• Restless sleep	
• Sleep talking	
• Sleep terror	
• Sleepwalking	
• Witnessed breathing pauses during sleep	

Table 1: Comparison of Symptoms in Children and Adults.

Diagnosis

Cycle during Sleep in OSA

Normal Cycle

Initially, light sleep or stage 1 of Non-REM sleep occurs and usually within 5 to 20 minutes go into a deeper sleep or stage 2. The deepest sleep is stage 3 and 4 Non-REM sleep. As we go into the deeper stages of sleep we become less arousable and the body's muscles become more relaxed. Normally REM sleep occurs more often and for longer periods in the early morning hours

In OSA Patients

Their breathing disturbance markedly interferes with their normal sleep patterns such that they may wake up very briefly but frequently, thus spending a majority of their sleeping time in Stage 1 and 2 Non-REM sleep and much less in Stage 3-4 and REM sleep. The result is that many people complain of a very unrefreshing sleep. Apnoeas tend to be more common and more severe during REM compared with Non-REM sleep.

How is Normal Breathing Restored during Sleep?

During the apnoeic event, the person is unable to breathe in oxygen and to exhale carbon dioxide, resulting in low levels of oxygen and increased levels of carbon dioxide in the blood. The reduction in oxygen and increase in carbon dioxide alerts the brain to resume breathing through upper airway muscles; breathing is resumed, often with a loud snort or gasp. Frequent arousals, although necessary for breathing to restart, prevent the patient from getting enough restorative, deep sleep.

Sequela

Results in excessive daytime sleepiness, performance and cognitive decrements, and cardiovascular dysfunction that include systemic hypertension, right heart failure, and cardiac arrhythmias The risks of undiagnosed obstructive sleep apnoea include heart attacks, strokes, impotence, irregular heartbeat, high blood pressure due to apnoea induced increased sympathetic nervous activity. The most obvious complication arising from OSA is diminished quality of life brought on by chronic sleep deprivation.

Morphology and Sleep Apnoea

The results from many studies demonstrate an interaction between craniofacial morphology and pharyngeal soft tissues. An association has been found between a forward tongue posture and an anterior open bite, a large overjet, a steep mandibular plane, and large gonial angle. In the current studies, a posterior position of the pharyngeal wall and a lengthening of the tongue has been seen with the following craniofacial features, a posterior maxilla and mandible, a clockwise rotated mandible, a steep occlusal plane, an increased height of the lower and upper face, extruded teeth, proclined incisors, and an open bite. These findings may have important implications for the pathogenesis of obstructive sleep apnoea Diagnosis.

Sleep disorders can be diagnosed and treatment planned either by physicians or by Dentists. Dentists should be able to recognize potential sleep-disorder patients, try to find the etiology. If the disorder is due to a medical problem, then patient should be referred to a physician, and if the disorder is due to some dental reasons then a Dentist must assist the physician in treating these patients with oral appliances when required.

OSA may be mild, moderate or severe, depending on the AHI or RDI. An index of fewer than 5 episodes per sleep hour is considered normal, 10 to 20 episodes per hour are mild, 20 to 40 is moderate and more than 40 is severe. All patients who suffer from OSA should undergo a full-night PSG and a subsequent Multiple Sleep Latency Test (MSLT). The Multiple Sleep Latency Test, performed during the day following PSG allows the patient five naps of up to 20 minutes each, at 2-hour intervals; the a time it takes a patient to fall asleep is a good measure of sleepiness. Currently, the MSLT is used selectively to evaluate patients further for hypersomnolence and for other sleep disorders.

Clinical Predictors to Diagnose Obstructive Sleep Apnoea

Clinical features alone cannot identify sleep apnoea accurately, but elements of the history and physical examination can identify patient's high risk for OSA. Age, gender, hypertension, body mass index, neck circumference, description of pharyngeal crowding based on modified Mallampati criteria and tonsillar size, morphometric measurements, arid patient symptom ratings have been investigated as independent risk factors for OSA. Prediction models are not widely used but may help the clinician to select more or less laboratory diagnostic testing based on each patient's OSA risk.

Another way to assess sleepiness is to use the Epworth Sleepiness Scale (ESS), a validated questionnaire that is widely used and easy to administer at each patient visit. The change in total score on the ESS is commonly used to indicate treatment response.

Evaluation

The way to find these patients is to be aware of the common signs and symptoms of obstructive sleep apnea and to carefully examine any patient who complains of snoring or daytime sleepiness.

Physical Examination

The physical examination is frequently normal in OSA, other than the presence of obesity (defined as a body mass index greater than 28 kg/m2) and neck diameter greater than 16 inches.

Oral Examination

The upper airway should be evaluated in all patients, particularly in non-obese adults with symptoms consistent with OSA. Malampati scores used in anaesthesia for determining the difficulty of performing an intubation as the tongue obstructs the airway is used to evaluate OSA .Scores of 3 and 4 are at a greater risk of sleep apnea Figure 4.

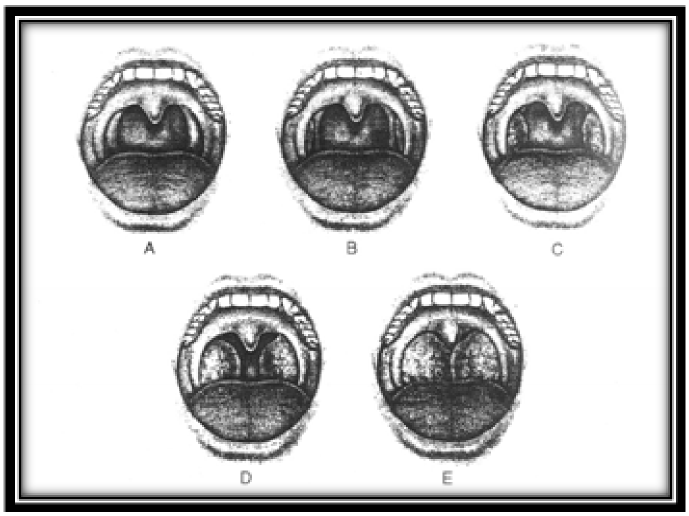

Figure 4: Enlarged tonsils-tonsil size is graded on a universally recognized standard.

- Retrognathia or micrognathia
- Soft palate edema/erythema
- High, arched hard palate

These patients may have an enlarged floppy uvula or tonsillar hypertrophy .An elongated soft palate that rests on the base of the tongue is another cause of the airway obstruction sometimes seen in patients with sleep apnea.

The Epworth Sleepiness Scale

It includes a set of self-administered questionnaire to relate the chances of dosing off in the following situations.

a) Sitting and reading.
b) Watching TV.
c) Sitting inactive at public place such as Theatre or meeting.
d) As a passenger in a car for hours without a break.
e) Lying down to take rest in the afternoon when the circumstances permit.
f) Sitting and talking to someone
g) Sitting quietly after lunch without alcohol.
h) In a car stopped in traffic for few minutes.

More than 10 is considered to be pathological and Epworth Sleepiness Scale indicates that sleep specialist should be consulted. ESS is useful in evaluating response to treatment. The ESS should decrease with effective treatment.

Polysomnography or PSG

A PSG is a physiologic study that is considered as the gold standard of Diagnosis of OSA. It is usually attended by a trained technologist performed for at least 6 hours during a patient's normal sleep hours. The study records sleep staging and other physiologic variables. Sleep staging includes electroencephalography (EEG), electro-oculography (EOG), and electromyography (EMG). Other physiologic parameters and variables that may be measured include ECG monitoring, airflow, respiratory effort, gas exchange (by oximetry, transcutaneous monitors, or end-tidal gas analysis), limb muscle activity, extended EEG, penile tumescence, gastroesophageal reflux, continual blood pressure monitoring, snoring, and body position.

Video monitoring is recorded for each patient to distinguish better among potential abnormal sleep behaviours including nightmares, nocturnal seizures, or rapid-eye-movement (REM) sleep behavioral disorder. The PSG is scored in separate 30-second epochs by a registered technologist, and then interpreted by a board-certified poly somnographer. Each 30-second epoch is assigned a sleep stage based on published normal patterns.

Figure 5: Polysomnography.

Sleep Heart Health Study for example, in 1995 defined an apnoea as "decrease of airflow amplitude below 25% of 'baseline' amplitude lasting for at least 10 seconds. Hypopnoea is defined a decrease of airflow amplitude below a 70% of 'baseline' amplitude, lasting for at least 10 seconds.

The PSG summary report usually describes the overall RDI, the RDI while supine, and the RDI while in REM sleep, and the lowest oxygen desaturation. Sleep architecture is displayed as a graph through the night, termed a hypnogram.

Some patients may overcome high airway resistance by generating increasing intrathoracic pressures with each breath, leading to an arousal without an apparent reduction in airflow or oxygen saturation. This type of SDB occurs in patients with upper airway resistance syndrome (UARS); a small but uncertain proportion of patients fall into this category of the spectrum of SDB. A significant shortcoming of PSG in clinical sleep medicine is its inability to diagnose UARS. Sleep-disordered breathing often is worse when patients sleep in the supine position and during REM sleep, so a single PSG may not always be representative of the true clinical condition.

Disadvantages

a) Sometimes, however, a patient does not sleep long enough to obtain all the data needed.
b) Polysomnographycan not provide data from patients who have mild OSA only at home or only after using certain medications or alcohol but who do not experience any episodes during the sleep study. Therefore, a polysomnogram must be interpreted with the entire clinical picture in mind.
c) Polysomnography is expensive and labor intensive

Split-Night Studies

To establish optimal therapeutic pressure, CPAP usually is initiated during polysomnography in the sleep centre. The pressure is titrated upward in small increments until apnoeic episodes are controlled or eliminated; often the patient then experiences increased or rebound REM sleep. A more reliable titration to effective pressure often requires an entire night of testing and may, for some patients, require a second PSG study dedicated to CPAP titration. For most patients, however, CPAP titration may be accomplished even after a 2-hour baseline evaluation without treatment [70].

A split-night study is especially useful after the physician has thoroughly discussed sleep apnea treatment options with the patient, and when the patient has a good idea of the nature, inconvenience, and treatment value of CPAP.

The AASM consensus statements recommend that CPAP be initiated a split-night study if four criteria are met:

1) An AHI of at least 40 is documented during a minimum of 2 hours of diagnostic polysomnography. Split-night studies may sometimes be considered at an AHI of 20 to 40, based on clinical judgment.
2) CPAP titration is carried out for more than 3 hours.
3) Polysomnography documents that CPAP eliminates or nearly eliminates the respiratory events during REM and non-REM sleep, including REM sleep with the patient in the supine position.
4) A second full night of polysomnography for CPAP titration is performed if the diagnosis of a sleep-related breathing disorder is confirmed, but the above two criteria are not met.

A split-night protocol may reduce the cost of diagnosis and treatment initiation for sleep apnoea patients, but it requires that the technologist make the initial diagnosis based on a partial-night recording which is suggestive of OSA.

Continuous Nocturnal Oxygen Saturation Measurement At Home

Using 10 desaturations per hour as the cutoff, it has 98% sensitivity but only 48% specificity with a positive predictive value of 61% and a negative predictive value of 97% in those with a history Figure 6.

Figure 6: Oxygen Saturation Measurement.

Disadvantages

a) Not valid in those receiving oxygen therapy
b) Can be used to screen before ordering a sleep study, since it has a high negative predictive value and is inexpensive

Limited-Channel Testing

Monitoring of cardio respiratory variables alone may be adequately sensitive to diagnose OSA in many patients. A limited-montage sleep study typically includes channels monitoring airflow, thoracic movement, abdominal movement, ECG rhythm recording, and SO Particularly applicable for patients with a high risk of sleep apnea based on history and physical findings, limited-montage testing requires fewer accessory recording devices, and post test scoring and analysis may be less complex than for a full PSG.

Pulse Oximetry

Arterial oxygen saturation can be monitored continuously by pulse oximetry in the emergency room, during surgery, and during PSG. Pulse oximetry is relatively simple and reliable, but technical problems including sensor movement can affect the measurements. SaO2 during sleep was 96.5mm Hg, and the lowest SaO2 was 90.4 mm Hg. Arterial oxygen saturation values were 1 to 2 mm Hg lower in healthy subjects over 60 years old.

Oximetry as a sole physiologic parameter has been investigated as a diagnostic test for OSA. Derived data usually include the total number of desaturations, the desaturation index (DI) or number of desaturations per hour, highest SaO2 lowest SaO2 mean SaO2 and cumulative time spent below 90% SaO2. Most investigators define a desaturation as a drop in SaO2 of 4%, but some define it as a drop of 3% or 5%.

Oximetry fails to diagnose adequately patients with a high RDI but with mild desaturations. Sensor movement during unattended oximetry at a patient's home often contributes to misleading data. False-positive results from oximetry may occur when patients with pulmonary disease develop desaturations unrelated to airway obstruction. Despite these limitations, almost all reports surveyed indicated that oximetry may be a useful diagnostic tool over a wide range in OSA severity. Oximetry may be useful, for example, to evaluate the response to treatment after surgery or airway dilator placement in patients with known OSA.

EMG Activity

Genioglossus

An increased size, altered shape, more upright posture and caudal extension facilitates the tongue`s fall backward due to gravity when OSA patients move from upright to supine position. GG activity is reduced during sleep and such a reduction in tone might result in a thickening of the muscle or posterior movement of the tongue. Women appeared to show a higher GG baseline EMG activity during spontaneous breathing at rest, while men were more responsive to the partial occlusion of the pharyngeal airway.

Portable Studies

Portable sleep studies are helpful for patients who cannot easily come to the sleep centre and for certain limited studies such as follow-up studies after surgery for sleep apnoea. The availability of PSG and CPAP titration at the hospital bedside, nursing facility, or home can be important. Studies at the home can make these same diagnostic and therapeutic services available more safely to patients with special needs, including those requiring respiratory treatments or frequent nursing care. Such extra care may not be available at the sleep centre.

Those who are good candidates for airway dilator as initial therapy:

1) Careful dental evaluation will identify those patients who are candidates for airway dilator treatment. Those with poor periodontal health or those who are edentulous may need alternate therapy and should be referred for sleep medicine evaluation.
2) If the patient has subjective sleepiness of moderate or severe degree, the dentist may consider referral for sleep medicine consultation and PSG.
3) If the patient with disruptive snoring has subjective sleepiness of mild degree, the dentist may consider referring the patient directly for PSG.
4) If PSG indicates that the patient has moderate to severe sleep apnoea, the dentist should reconsider referral for sleep medicine consultation. If PSG indicates the absence of moderate to severe sleep apnoea, airway dilator therapy is an appropriate treatment.
5) The patient's clinical criteria should be followed regularly. If clinical complaints are not improving, the patient should undergo sleep medicine consultation.

Other Imaging Techniques for the Snoring and Sleep Apnoea Patient

Precise anatomic information about the upper airway and surrounding soft tissue structures can be obtained with MR and computed tomography (CT) imaging, allowing the evaluation of both the donut and the hole in the centre of the donut. MR and CT imaging have provided important data on the dimensional changes in the upper airway soft tissue and craniofacial structures during respiration, sleep, and airway closure. Moreover, volumetric three-dimensional reconstructions of the airway and surrounding soft tissue structures obtained from MR imaging scans can objectively quantify anatomic structural risk factors in patients with obstructive sleep apnoea.

The ideal upper airway imaging modality for patients with obstructive sleep apnoea would be inexpensive, non-invasive, permit supine imaging, and not expose the patient to ionizing radiation. Such an imaging technique should also be capable of performing dynamic state-dependent imaging and allow for three-dimensional volumetric reconstructions of the upper airway and surrounding soft tissue structures. Although an ideal imaging modality does not yet exist, MR imaging is probably the best method currently available for assessing the upper airway and surrounding soft tissue structures.

Acoustic Reflection

Acoustic reflection is a non-invasive imaging technique based on analyzing sound waves reflected from upper airway structures. The phase and amplitude of the reflected sounds waves can be transformed into an area-distance relationship. The technique is generally performed through the mouth, is free of radiation, and because it is both fast and reproducible, permits dynamic imaging of the upper airway. Studies using acoustic reflection have demonstrated reductions in the upper airway area of apnoeics compared with normal controls.

Fluoroscopy

Fluoroscopy has also been used to study upper airway closure in patients with sleep apnoea. Fluoroscopic studies during sleep have demonstrated that upper airway closure occurs in the retropalatal region for most patients with sleep apnoea. Although fluoroscopy can provide a dynamic evaluation of the upper airway during wakefulness and sleep, radiation exposure makes this study impractical for routine use.

Nasopharyngoscopy

Nasopharyngoscopy is commonly used to evaluate the nasal passages, oropharynx, and vocal cords. Although it is invasive, nasopharyngoscopy is easily performed and does not involve radiation exposure. Moreover, it permits direct observation of the dynamic appearance of the pharynx. Nasopharyngoscopy has been used in a number of studies to evaluate physiologic changes in the hypotonic airway, stat-dependent airway changes in patients with obstructive and central sleep apnoea, and the effects of mandibular-repositioning oral appliances, weight loss, and uvulopalatopharyngoplasty (UPPP) on airway caliber. Nasopharyngoscopy, however, examines only the lumen of the upper airway and does not provide measurements of the surrounding soft tissue structures.

Cephalometry

Cephalometry is a standardized lateral radiograph of the head and neck used to examine upper airway craniofacial and soft tissue structure. The technique is widely available, easily performed, and much less expensive than either CT scanning or MR imaging. Cephalometry, however, must be performed in a standardized fashion with the head stabilized and with the radiograph obtained at end-expiration, because upper airway caliber is affected by the respiratory cycle. Cephalometry is considered useful for evaluating and quantifying craniofacial (mandibular and hyoid position) and soft tissue structures (tongue and soft palate) in patients with retrognathia or micrognathia. Cephalometrics have also been used to evaluate skeletal structure before facial surgery (mandibular advancement, bimaxillary advancement, sliding mortis genioplasty) and to evaluate the efficacy of oral appliances.

The low cost and widespread availability of cephalometrics make it useful for sleep apnoea patients being treated with oral appliances and undergoing craniofacial surgery Figure 7.

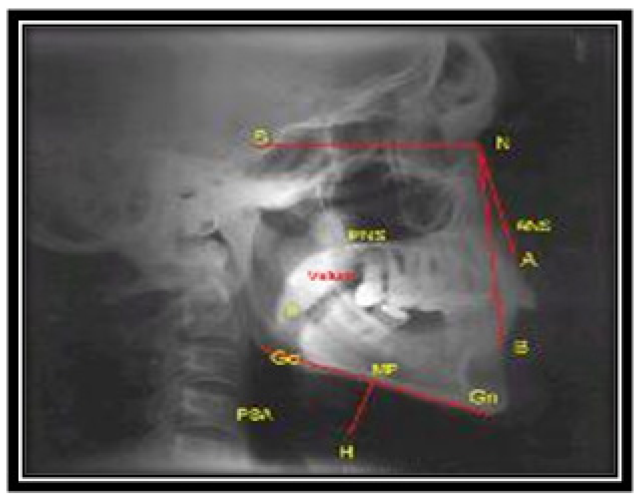

Figure 7: Cephalometric Landmarks.

Common Findings

a) Mandibular retrognathia
b) Retruded maxilla
c) Posterior vertical maxillary deficiency
d) Retropositioned tongue
e) High mandibular plane angulation,
f) Short chin-neck line
g) Decreased PAS
h) Poor definition of gonial angles
i) Class II dental occlusion (but sometimes Class I)

j) Steeper and shorter anterior cranial base
k) Longer soft palate

Some other characteristics that may be seen in these patients are nasal airway obstruction (ie, narrow nostrils, wide columella, enlarged turbinates, deviated septum, polyps, nasopharyngeal adenoid tissue, decreased posterior choanal height, etc) and oropharyngeal abnormalities (elongated soft palate, medially and posteriorly positioned posterior faucial pillars, enlarged adenoids, hyperplastic tonsils, macroglossia, etc). Riley et al found that a PAS of less than 11 mm and a mandibular plane-hyoid boneangle greater than 15.4° was indicative of OSA.

Patients with severe craniofacial anomalies such as the Pierre Robin syndrome, who exhibit micrognathia of the mandible and glossoptosis, tend to develop upper airway obstruction. Skeletal features thought to be of diagnostic importance in OSA include a retrognathic mandible, a narrow mandibular arch, maxillary and mandibular retrognathia, an increased lower facial height, a downward and forward positioned hyoid bone, a reduced size of the pharynx, and an increased craniocervical angle. Those soft tissue entities that are visible in a sagittal cranial x-ray and that may be important in the diagnosis of OSA include enlarged tonsils and adenoids, increased tongue and soft palate areas, and a reduced distance between the base of the tongue and posterior wall of the pharynx.

Cranial base angle was reduced. The angle of the cranial base (BaSN: V2) was similar in the two groups. The bony pharynx opening (BaPns: V3) was reduced. The lower face height (LFH: V10) was increased in the SAS group; occlusal plane (SNOP: V12) and mandibular plane (SNMP:V13) were steeper in this group. The mean sagittal dimension of the midface (DcA: V7) was reduced in the SAS population. The real length of the mandible (DcGn: V8) was identical in the two groups.

Changes in Supine

Supine films provide a more realistic anatomical picture of the airway and surrounding structures. The soft palate and tongue occupy a larger proportion of the airway in this position and the hyoid moves anteriorly and inferiorly in both snorers and OSA subjects as shown by Battagel, AmaJohal EJO 2002.

Supine lateral skull films were obtained using an adjustable Orbix machine. Subjects lay supine with a foam head support placed in a position that resembled as closely as possible that which they adopted during supine sleep. Contrast medium was applied to the tongue and the subjects were asked to place their teeth in light occlusion. Lateral head position was carefully aligned and all films were taken at end-expiration. This procedure was adopted because was not possible to obtain supine recordings using the cephalostat.

Upright and supine cephalometric evaluation of obstructive sleep apnea syndrome and snoring subjects.

In the upright seated position, the cephalometric variables demonstrated that patients with OSAS had more counterclockwise rotation of the middle cranial fossa, more obtuse angulation of posterior wall of the maxilla to cranial base), shorter ramus width relative to middle cranial fossa, shorter effective dimension of maxilla with counterclockwise rotation of palatal plane when related to PM line and a smaller ratio of lower anterior facial height to middle anterior facial height. When changing from the upright to the supine position, both the OSAS and snoring groups demonstrated a reduction in the superior-posterior pharyngeal space. In the snoring group, the hyoid bone moved anteriorly when changing from upright to supine position.

Hyoid Position

A descending position of the hyoid with increasing age is due to the tongue's increasing in bulk and becoming larger in relation to the intermaxillary space, a trend that is pronounced in males. This jeopardizes the volume and resistance of the upper airway. Inferior hyoid bone position in patients with OSAS may be a secondary effect because of an attempt to maintain patency of the upper airway passage.

Craniocervical Angle

Apneic subjects had a craniocervical extension and forward head position compared with nonapneic subjects as it was found to enlarge the airway (lower oropharyngeal and hypopharyngeal levels).

Tongue Length

The tongue length in the OSAS group was significantly longer, the superior-posterior pharyngeal space was shorter, the position of the hyoid bone was more inferior and the ratio of tongue to intermaxillary area was higher than the control group.

Head Form

However, a mismatch between facial form and head form was found for the OSAS group. Amis and Kurpershoek11 assessed the pattern of breathing in 19 brachycephalic dogs (English Bulldogs and Boston Terriers). Their results suggested that brachycephalic dogs may be at risk for the development of disordered breathing during sleep. The term brachycephalic airway syndrome has been used in veterinary medicine to describe a condition related to upper airway obstruction associated with the anatomy of the brachycephalic skull.

Palatal Plane

The anterior portion of the palatal plane to occlusal plane was increased compared to the height between the occlusal plane and mandibular plane. Partinen, et al. determined that an increased mandibular plane to hyoid bone distance and decreased width of the posterior airway space were significant predictors of elevations in AHI. A cluster analysis by Tsuchiya et al further suggests that individuals with favorable craniofacial structure may tolerate massive weight gain without developing clinically significant upper airway obstruction. In contrast, patients with abnormal skeletal structures can develop OSAS even in the absence of obesity.

Radiographs

Radiographic studies that have been found to be useful include lateral neck films that can demonstrate adenotonsillar hypertrophy and some other airway lesions. The significant advantages of cephalometry are its easy access, low cost, and minimal radiation. The exposure should be taken at the end of the expiration Figure 8.

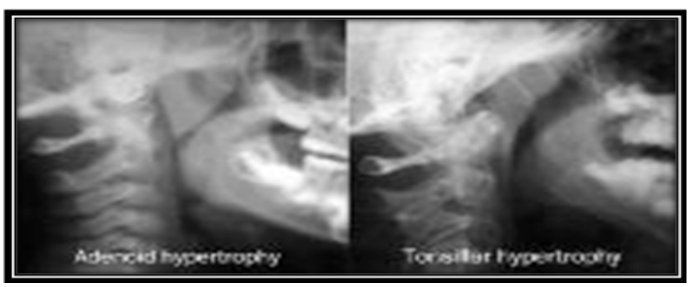

Figure 8: Showing Adenoid and Tosillar Hypertrophy.

Computed Tomography

Computed tomography provides excellent resolution for upper airway soft tissue and craniofacial structures. Three-dimensional volumetric reconstructions of upper airway, soft tissue, and bony structures can be obtained from axial CT images. Moreover, helical CT scanners provide direct acquisition of volumetric images. Dynamic imaging of the upper airway can be performed with electron beam CT, which provides excellent temporal (50 millisecond ms) and spatial resolution. Compared with MR images, however, CT scanning has limited soft tissue contrast resolution, particularly for upper airway adipose tissue. In addition, CT scanning is relatively expensive and exposes the patient to radiation.

Most studies that used CT to examine airway caliber during wakefulness and sleep have demonstrated narrowing in the retropalatal region of patients with obstructive sleep apnoea. Volumetric CT studies in obese patients with sleep apnoea have demonstrated a smaller upper airway and a larger tongue volume Figure 9.

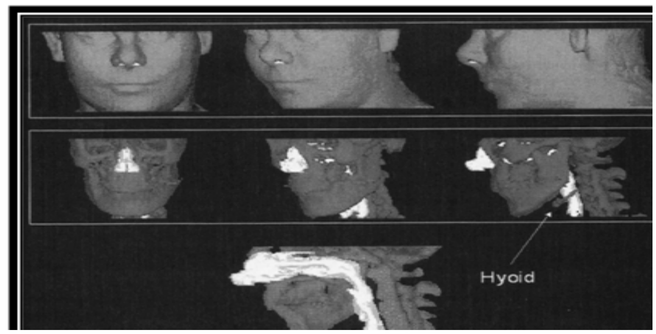

Figure 9: CT scan Showing Airway.

Dynamic imaging with electron beam CT has provides detailed information about the changes in upper airway caliber during the respiratory cycle. However CT provides only axial Images and cannot image the entire pharyngeal airway in a single plane.

MR Imaging

In 1992, a group in Japan reported the use of ultrafast MRI and found that it has the advantages of being noninvasive with high contrast resolution, allows scanning in multiple planes, allowing the whole airway to be visualized at one time.

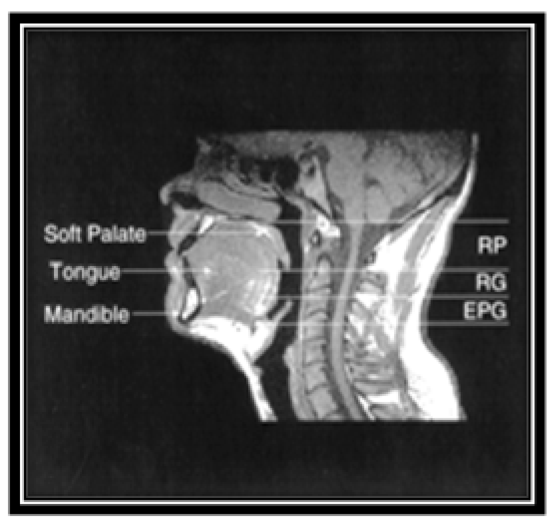

Figure 10: MRI of Pharyngeal Airway.

MR imaging is perhaps the most useful imaging technique for studying obstructive sleep apnoea because it provides excellent resolution of upper airway and soft tissue (including adipose tissue), accurately measures cross-sectional airway area and volume, allows imaging in the axial, sagittal, and coronal planes, provides data suitable for three-dimensional reconstruction of upper airway soft tissue and craniofacial structures, can be performed during wakefulness and sleep, and does not expose subjects to radiation. A single excitation is used to obtain mid-sagittal and axial projections during transnasal shallow respiration at rest, simulation of snoring Figure 10.

Using Muller's manoeuvre the motion of the tongue, soft palate, uvula and posterior pharyngeal surface can be visualised by obtaining 5-6 images per second. If the pharyngeal cavity is seen to be disappearing in trans-axial and sagittal planes, obstruction is diagnosed. Narrowing is said to be present if the pharyngeal cavity disappears only in one of the images and if there is more than 50% reduction in the pharyngeal space during sleep as compared to maximum area seen in wakeful state. Reduction in airspace up to 50% is considered normal. As the functional factor is different during sleep and wakefulness; imaging should be done in both states Figure 11.

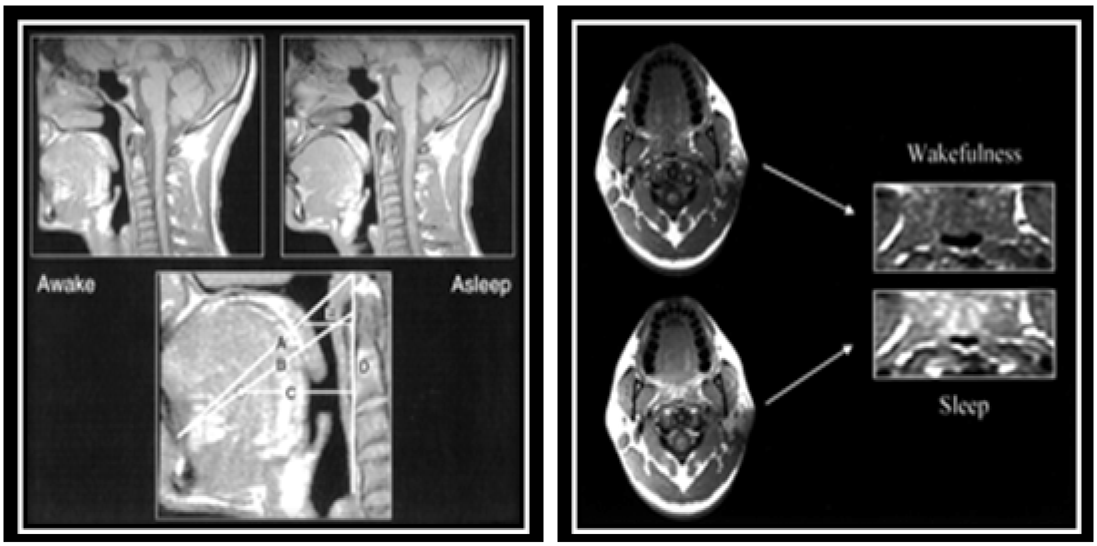

Figure 11: MRI Using Mullers Manoenvre.

MR studies cannot be performed on patients with ferromagnetic implants or pacemakers, patients who weigh more than 300 pounds, or patients who are claustrophobic. Moreover, achieving sleep in the MR scanner is difficult because of the associated noise. Thus, MR imaging is a powerful, non-invasive research tool for accurate, volumetric quantification of the upper airway and surrounding soft tissue structures that does not expose patients to radiation.

Disadvantage

The studies done with MRI described only sites of airway obstruction, and did not measure, cross-sectional airway area, airway volume, or soft-tissue dimensions Figure 12.

Figure 12: MRI showing sites of Obstruction.

Features of Upper Airway Soft Tissue and Craniofacial Structures in Relation to OSA

A static upper airway imaging

a) Smaller upper airway.
b) Narrowing in retropalatal region.
c) Decreased mandibular body length.
d) Inferiorly positioned hyoid bone.
e) Retro positioning of maxilla.
f) Size of the upper airway soft tissue is greater and longer soft palates, wider Uvula.
g) Increased cross sectional area and volume of the soft palate, tongue, parapharngeal fat pads, and lateral pharyngeal well, turns to narrowing of upper airway.
h) In quantitative the mapping, suggest that edema or fat content of the tongue muscles is greater in patients with OSA than in normal controls.
i) Increased neck size.
j) Increased upper airway adipose tissue (primarily deposited in the lateral parapharngeal fat pads).
k) Increased fat deposits in mandibular ramus, within tongue and soft palate.
l) Greater percentage of muscle in the uvula, in patients with OSA than in normal controls.
m) Increased type II fast twitch fibers in genioglosses of patients.
n) Macroglossia (especially in children trisomy 21)
o) Enlarged tonsil
p) MRI state that, increased thickness of lateral pharyngeal muscular walls than enlargement of parapharyngeal fat pads or tongue was the predominant anatomic factor causing airway narrowing.

Dynamic Upper Airway Imaging

Electron beam CT scanning during wakefulness has analyzed upper airway anatomic changes that occur during inspiration and expiration in normal persons and in patients with sleep apnoea. These studies identified four distinct phases of the respiratory cycle with respect to upper airway dimension. There is a small increase in upper airway area at the onset of inspiration that presumably reflects increased activity of the upper airway dilator muscles. Upper airway area is relatively constant during most of inspiration, suggesting a balance between negative intraluminal pressure - which would decrease airway caliber - and the action of the upper airway area increases in early expiration, presumably because of positive intraluminal pressure. Upper airway area is greatest during this phase of the respiratory cycle. Upper airway size is substantially reduced at the end of expiration, presumably because it is no longer kept open by the phasic action of the upper airway dilator muscles or positive intraluminal pressure. Indeed, these data suggest that upper airway narrowing or collapse may be particularly likely to occur at the end of expiration [71].

Other upper airway imaging studies using CT scanning and nasopharyngoscopy have also demonstrated that airway caliber is smallest at the end of expiration that airway closure in apnoeics occurs during expiration, not during inspiration.

Studies using ultrafast MR imaging have confirmed these findings and have demonstrated an inverse relationship between the size of the lateral pharyngeal walls and airway caliber. The lateral pharyngeal walls remained relatively constant in size during inspiration, thinned in early expiration, and thickened towards the end of expiration. The Muller's maneuver a forced inspiratory effort with the mouth closed and the nose occluded, is thought to simulate an apnoeic event. Reductions in upper airway caliber during a Muller's maneuver are directly related to reductions in intraluminal pressure which are effort directly related to reductions in intraluminal pressure which are effort dependent.

The study found that during a Muller's maneuver:

a) Upper airway area is progressively reduced in the retropalatal region as intraluminal pressure becomes more negative.
b) Retropalatal narrowing is significantly greater than the retroglossal narrowing at all pressure levels.
c) Retroglossal area does not change significantly, but there is an alteration in airway configuration consisting of a decrease in the lateral and an increase in the anterior-posterior airway dimensions.
d) Airway narrowing is significantly greater in the lateral than the anterior-posterior dimension at all pressure levels.
e) Changes in body position do not result in a significant difference in airway caliber or dimension.

State-Dependent Upper Airway Imaging

In addition to static and dynamic upper airway imaging, state-dependent imaging studies performed during both wakefulness and sleep has also advanced the understanding of the pathogenesis of sleep apnoea.

The retropalatal airway narrowing during sleep is caused by a reduction in both anterior-posterior and lateral airway dimensions. The state-dependent reduction in the lateral airway dimensions is mediated through thickening of the lateral pharyngeal walls, whereas the anterior-posterior narrowing is primarily related to posterior movement of the soft palate. These findings indicate that thickening of the lateral pharyngeal walls and posterior movements of the soft palate are both important in the biomechanics of airway narrowing during sleep in normal persons and potentially in patients with sleep-disordered breathing.

Horner, et al. demonstrated that airway obstruction during Sleep is caused by both posterior displacement of the soft palate and tongue and lateral displacement of the pharyngeal walls.

Possible mechanisms causing the lateral walls to thicken during sleep include:

a) A reduction in muscle tone with concomitant thickening and shortening of these muscles.
b) A decrease in lung volume which could reduce the effect of tracheal tug and potentially increase the thickness of the lateral walls.
c) Biomechanical changes in the configuration of the hyoid, mandible, tongue, and soft palate which, in turn, could affect the lateral walls. Dynamic and volumetric three-dimensional imaging may be necessary to understand biomechanical changes in the lateral pharyngeal walls during sleep.

Treatment

Selection of treatments for individual OSA patients should be based upon balanced consideration of disease severity and site's of obstruction, subjective symptoms, risks of morbidity and mortality, and patient choice. Treatment effectiveness is variable and dependent on patient needs. It is believed that treatment must be evaluated over time for good patient outcome.

The proposed management of the patient's sleep disorder should include proper diagnosis, along with consultation and the recommendations of the treating physician, and on the desires of the patient. Adjunctive measures that may be undertaken include weight loss, nutritional counselling, exercise, the use of a special cervical pillow, smoking cessation, alcohol counselling, or the alteration of the patient's sleep position.

In most instances the dentist involved in the management of the sleep-disordered patient focuses on the management of a breathing-related disorder. The use of an appliance to advance the mandible or some form of a surgical procedure comprises the most significant component of the treatment. Treatment therapy could either be Non-Specific or Specific.

Nonspecific Therapy

These measures should be included in the treatment of all patients with OSA but should be used exclusively only in patients with very mild apnoea whose main complaint is snoring.

a) Losing weight.
b) Should avoid the use of alcohol for 4-6 hours prior to bedtime, and sleeping pills.
c) Positional therapy can be used to treat patients whose OSA is related to body positioning during sleep.

There are several strategies which can help patients who have mild apnea only when lying on their back. One is to sew or attach a sock filled with tennis balls, length-wise down the back of their pajama top or nightshirt. This makes it uncomfortable for the sleeper to lie on their back, and they usually will move onto their side. Another technique is to use positional pillows to assist in sleeping on the side. Positional therapy has its limits, but it has been tried with success in some patients.

Specific Therapy

The specific therapy for sleep apnea is tailored to the individual patient based on medical history, physical examination, and the results of polysomnography. Medications are generally not effective in the treatment of sleep apnea.

Steps in Treatment Plan

1) Behavior modifications.
2) Medications.
3) Positive airway pressure therapy.
4) Oral Appliances.
5) Surgical treatment.

Behavior modifications: It is possible to correct snoring and OSA problems simply by suggesting modifications in certain areas of behaviour such as sleep position, alcohol use, sedative use, smoking, and the patient's weight. It has been noted that many snoring patients snore only when they sleep on their backs. To prevent these patients from having to use devices or undergo surgical procedures, different suggestions have been made. A common suggestion is having patients lie on their side and place a pillow behind them so they cannot roll onto their back. Another suggestion is sewing a tennis ball into the centre of the back of their pajamas to serve the same purpose. There are commercial devices that may perform the same function. Another type of commercial device attaches to the patient's finger and detects the sound of snoring. When the sound is heard, the device vibrates or shocks the patient's finger to arouse the patient. This particular type of device, however, would seem make acquiring a sufficient quality and quantity of sleep more difficult. It does seem reasonable that if a patient snores only while on his or her back, an attempt should be made to change the sleep position.

The elimination of alcohol and sedatives for the last 3 hours before sleep has been suggested because of the depressing effect of these drugs on the central nervous system. They may act as muscle relaxants, thereby contributing to the loss of muscle activity maintaining airway patency.

Probably the treatment option with the greatest chance of success is weight loss. With an increase in weight comes a loss in diameter of the upper airway because fat deposits accumulate in the walls of the pharynx. It is believed that as the body mass index (BMI) of a patient becomes 10% above ideal, the loss of airway space becomes significant. When asked, patients will often agree that they began to snore and have breathing problems when they gained weight. It should be suggested that, with the concurrence of their physician, these patients lose excess weight and attempt to reach their ideal BMI. Many patients can be cured simply by losing weight.

Medications: Even though listed as an option for physicians, little success has been demonstrated with the use of medications by these patients. Thyroid hormone supplementation might lead to significant correction of the apnoea if this is the sole problem. Control of blood sugar levels has, however, had at best a moderate effect in controlling the diagnosed obstructive sleep apnoea. Certain medications which increase respiratory drive are helpful in some patients.

a) **Progestational Agents-**Estrogen has shown to be used in central sleep apnoea and obesity hypoventilation syndrome not used in obstructive type.
b) **Opiod Antagonists and Nicotine-**shown to improve oxygenation not clinically useful as these are short acting and disrupt sleep cycle
c) **Acetazolamide-**produces metabolic acidosis and stimulates ventilatory control centrally very useful in periodic breathing and central sleep apnoea may be helpful in OSA
d) **Tricyclic Antidepressants--** Protriptyline has been used in people with mild apnea and snoring with mild success. It increases upper airway neuromuscular activity and decreases REM sleep. Protriptyline is not considered primary therapy for OSA. Consider use in a person with mild apnea who does not want CPAP or an oral appliance. Increases synaptic concentration of serotonin and/or norepinephrine in CNS by inhibiting their reuptake by presynaptic neuronal membrane.
e) **Modafinil--** May exert stimulant effects by decreasing GABA-mediated neurotransmission. Improves wakefulness in patients with excessive daytime hypersomnolence. The use of modafinil can be recommended for patients who (1) regularly use CPAP (defined as >4 h/night for >5 night/wk), (2) have an ESS >10.

The FDA recently approved the use of modafinil for the management of residual EDS in patients with OSA on nasal CPAP.

Central Nervous System Stimulants

Non Amphetam-- Used for treatment of fatigue without interfering with normal sleep architecture. They promote wakefulness.

Theophylline-Evidence exists to support its use in central sleep apnoea. Also reduces obstructive events but causes severe sleep disruption

The search for a pharmacological agent to treat OSA has been disappointing though some patients respond to treatment.

Positive Airway Pressure Therapy

It has three forms:

- Continous Positive Airway Pressure Therapy (CPAP)
- Autotitration
- Bi-level Positive Airway Pressure

Continous positive airway pressure therapy

The first reported use of nasal continuous airway pressure for OSAHS in adults was by Sullivan, et al. [18]. In 1983, the nasal mask delivery system, similar to contemporary systems, was introduced. Fundamentally, the application of a therapeutic level of CPAP results in immediate relief in the upper airway obstruction. This benefit has been attributed to the CPAP functioning as a "pneumatic splint" for the upper airway. Additional physiologic benefits of CPAP application have been shown to include improvement in the function of pharyngeal dilator muscles, ventilator drive, and upper airway morphology. CPAP rarely results in serious side effects. However, about 25% of patients may develop nasal congestion with chronic use Figure 13.

Figure 13: Continous Positive Airway Pressure Therapy.

Mechanism of CPAP

CPAP is administered at bedtime through a nasal or facial mask held in place around the patient's head. The mask is connected to a small air compressor which sends air under pressure through the tube into the mask, where it imparts positive pressure to the upper airways. This essentially "splints" the upper airway open and keeps it from collapsing in the deeper stages of REM sleep. Regardless of the mechanism used it is desirable to use the lowest possible pressure to eradicate the sleep apnea. It is necessary to titrate the pressure to each individual patient during a polysomnogram. Approximately 55 percent of patients who use CPAP do so on a nightly basis for more than four hours. It is the most commonly prescribed treatment for OSA. CPAP decreases blood pressure, primarily in patients with severe OSA. Evidence also suggests that CPAP may improve left ventricular ejection fraction in patients with congestive heart failure and OSA Figure 14.

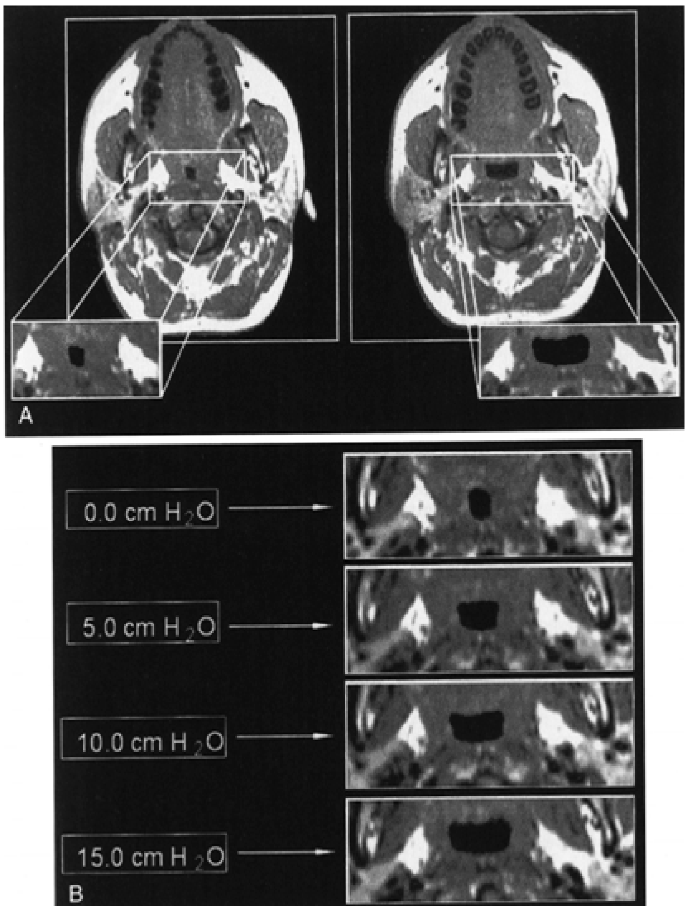

Figure 14: Pre and Post treatment CT of patient treated with CPAP.

The post treatment improvement of potential surrogate markers for cardiovascular mortality such as blood pressure, endogenous catecholamine levels, and muscle sympathetic neural activity has been shown. There is now convincing evidence of an impendent association of OSAHS with hypertension. Reduction in blood pressure levels with CPAP therapy.

The introduction of automatically adjusting CPAP devise over the past several years represents a significant advancement in CPAP technology since its inception in 1981. The device continuously adjusts the applied airway pressure to an "optimum" level throughout the night and appears to improve compliance. Alcohol intake can also depress the tone and contractility of the pharyngeal muscles, resulting in higher pressure requirements to maintain pharyngeal patency. Therefore, a single pressure level, as with standard CPAP, could result in a situation in which the pressure is excessive for parts of the night, but may be insufficient at other times, particularly after alcohol consumption.

Kuna and colleagues, however, using CT scanning, demonstrated that upper airway dilatation with CPAPL is greatest in the lateral dimension. An MR imaging study confirmed Kuna's findings and showed that progressive increased airway volume and area and lateral airway dimensions in the retropalatal and retroglossal regions (than the increase in the anterior-posterior dimensions).

Advantages

1) Tissues are prevented from collapsing during sleep, and apnoea is effectively prevented without surgical intervention.
2) Daytime sleepiness improves or resolves
3) Heart function and hypertension improve
4) Quality of life improves
5) Survival rates may increase
6) Therapy improves obstructive sleep apnoea, mixed apnoeas and some central apneas.

Disadvantages

1) Many patients find the mask uncomfortable, claustrophobic or embarrassing.
2) Since CPAP is not a cure and must be used every night for life, non- compliant patients experience a full return of obstructive sleep apnoea and related symptoms.
3) The sound of the machine may be disruptive.
4) Difficulty in exhaling
5) Inability to sleep
6) Nasal congestion
7) Sore eyes
8) Sore or dry throat
9) Headaches
10) Abdominal bloating
11) Chest muscle discomfort
12) Nose bleeding
13) Mask-related problems such as rash, skin abrasions etc
14) Conjunctivitis (from air leakage)

Autotituration

Autotitration devices are designed to provide the minimum necessary pressure at any given time and change that pressure as the needs of the patient change. The Auto Set acts by monitoring the patient's inspiratory flow-time curve.

Monitoring and responding to the flow-time curve, reduces the number of respiratory events and arousals improving sleep quality [72].

BI-Level Positive Airway Pressure

Bi-level positive airway pressure Because the air pressure required to prevent respiratory obstruction is typically less on expiration than on inspiration, bi-level positive airway pressure machines are designed to sense when the patient is inhaling and exhaling and to reduce the pressure to a preset level on exhalation. Bi-level positive airway pressure machines usually are used when the patient does not tolerate CPAP or when the patient has more than one respiratory disorder.

Oral Appliances

Dentists must not become the primary care providers for these patients or attempt to treat a medical problem with an oral appliance without a proper diagnosis, which usually requires a sleep study and can only be diagnosed by a physician. Dentists must also be able to treat the patients referred by physicians and to follow accepted procedures when fabricating, inserting, titrating, and providing follow-up care for oral appliance therapy.

Indication

Oral appliances are indicated for use in patients with

(i) primary snoring or mild OSA who do not respond or are not appropriate candidates for treatment with behavioural measures such as weight loss or sleep position change;

(ii) Patients with moderate to severe OSA should have an initial trial of nasal CPAP because greater effectiveness has been shown with this intervention than with the use of oral appliances;

(iii) Oral appliances are indicated for patients with moderate to severe OSA who are intolerant of, or refuse treatment with, nasal CPAP. Oral appliances are also indicated for patients who refuse or who are not candidates for tonsillectomy and adenoidectomy, cranial facial operations or tracheostomy.

Presently, 38 oral appliances are commercially available. The basic mode of function of these oral appliances is to prevent the tongue from approaching the posterior wall of the pharynx and causing an obstruction. This posterior movement of the base of the tongue is minimized or prevented by use of either a tongue retaining device (TRD) or a mandibular advancement device (MAD), both of which are comprised of concomitant maxillary and mandibular appliance components.

Limitations to Oral Appliances

Mandibular protrusion devices should only be used when a patient has at least 8 teeth in each arch and is able to demonstrate a mandibular protrusion of at least 5 mm and a bite opening of greater than 25 mm. Appliances may be used in combination with partial dentures that replace no more than 4 teeth. Patients with edentulous maxillary arches and at least 8 teeth in the mandibular arch may be able to wear some mandibular protrusion devices, especially those that are fabricated with heat-softening acrylics. Totally edentulous patients are usually not good candidates for mandibular repositioners, but tongue retaining devices may be used in edentulous patients, although these appliances only have FDA clearance for snoring, not OSA.

Whereas slight TMJ discomfort can be relieved with forward mandibular positioning, OSA patients who present with more severe TMJ pain probably are not good candidates for treatment with mandibular protrusion appliances. Patients with significant bruxism can frequently damage mandibular protrusion devices and thus make this treatment approach costly and inefficient, while very obese patients, with some exceptions, are best treated by other means than mandibular protrusion.

Types of Oral Appliances

1) Tongue retaining device
2) Mandibular anterior positioner
   - adjustable
   - non adjustable
3) Soft palate or uvula lifting device

Tongue-Retaining Devices: Tongue-retaining devices were first described in 1982. They consist of a hollow bulb supported by trays that fit over the maxillary and mandibular teeth or edentulous ridges. To prevent the tongue from approaching the posterior wall of the pharynx, the patient projects the tip of the tongue into a hollow bulb, thereby creating a suction which retains the tongue in an anterior position Figure 15.

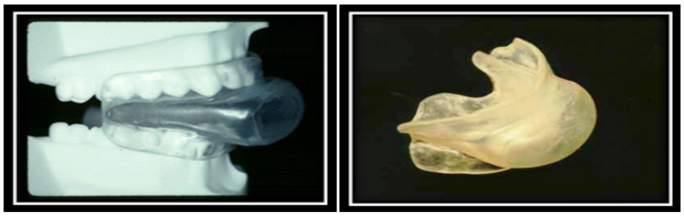

Figure 15: Tongue Retaining Device.

Advantage

Found to be most useful in patients with very large tongues, poor dental health, no teeth, chronic joint pain, or if their sleep apnoea is worse when lying on their backs than when they lie on their sides at night Figure 16.

a) TRDs can be used on edentulous patients as they do not require presence of dentition for retention.
b) TRDs will not loosen restorations because they do not require the retention as compared to that of Mandibular Advancement Devices.
c) TRDs require minimal or no adjustments.
d) TRDs cause minimal sensitivity in teeth or in the temporomandibular joint.
e) Tongue-retaining devices are effective in offsetting fluctuation of genioglossal muscle activity and in treating patients with OAS.

Figure 16: Modified Tongue Retainer in position.

Cannot Be Used In

People who are tongue-tied, so overweight that they are more than 50 percent above their ideal body weight, grind their teeth at night, or have chronically stuffy nose. Patients complain most often about irritation on the tip of their tongue (which can be painful, or cause irritation to spicy and salty foods). Patients also require practice in swallowing with the appliance in-place, because the tongue cannot move in its normal pattern. This appliance also forces nasal breathing and can be difficult to use if the patient has a stuffy nose or allergies.

Example (Arttoright, samelson): It procedure clockwise mandibular rotation while holding the tongue in a forward position during sleep. The devices one both pre and custom fabricated to maintain lingual protrusion with suction derived from a plastic bulb that is held between the tip and teeth. It increases the oropharngeal, velopharyngeal and hypopharyngeal cross sectional areas of the upper airway thereby improving airway patency and function.

Mandibular Advancement Devices

Mandibular advancement devices were first described by Robin in 1934. In general, MADs consist of firm-fitting trays that fit over the maxillary and mandibular teeth. Mandibular advancement devices may be fixed-position, with no allowance for adjustability for advancement or retrusion of the mandible, or adjustable. Almost all MADs require that the patient have a sufficient number of teeth so the device will be highly retentive, generally on both arches but at least on the maxillary arch.

Oral appliance therapy that involves advancement of the mandible has been shown to significantly decrease AHI in mild to moderate cases and in some cases with moderate to severe AHI. One study demonstrated a 27.6% increase in partial air volume with MAD. Matsumi, et al. showed that a compromised airway can be almost completely restored by moving the mandible forward to 100% of its protrusive capability.

Adjustable oral appliances are generally preferred because they can be adjusted in an anteroposterior direction until an acceptable level symptom improvement has occurred, while teeth or temporomandibular joint sensitivity is controlled. With either a fixed or adjustable device, the initial position of the mandible is generally approximately 70% 75% of maximum protrusion relative to maximum retrusion. With fixed-position oral appliance, this position is obviously the final maxillo mandibular position. The adjustable oral appliances have a built-in adjustment mechanism, often a screw mechanism Figure 6, with which titrate the oral appliances by moving the mandible posteriorly or anteriorly to achieve the desired results and an acceptable level of patient comfort. Therefore, the oral appliances are completely adjustable within the limits of the mechanism.

Some oral appliances may be made from a prefabricated standard set, similar to alginate impression trays, and can be fabricated chair side in the clinical setting. Others must be custom fabricated on a set of casts by a laboratory and some laboratories also require interocclusal records with which to mount the casts.

Insertion of Oral Appliances

Oral appliance therapy is not simply an insert-and-forget treatment modality. The proper positioning of the mandible may be time-consuming and, once completed, may require later repositioning. Many of the present oral appliances are filled or lined with a thermoplastic material which allows a comfortable and appropriate fit retention.

The oral appliance that incorporates thermoplastic material is initially heated in warm or hot water. Once the thermoplastic material is softened, the oral appliance is inserted, and any excess thermoplastic material is adapted to the buccal and lingual surfaces of the teeth using the fingers. The oral appliance should be removed and reinserted several times as the material chills to prevent it from becoming locked into undercut areas. After the oral appliance is removed and chilled, all thermoplastic or tray material is removed from contact with the gingiva using a warmed laboratory knife or acrylic burs. If an acrylic bur is used, the oral appliance must be chilled in iced water every few seconds prevent overheating and possible distortion.

Once excess material has been removed, an attempt is made to reinsert the oral appliance. At this point, the appliance may not reseat because of the presence of chilled and hardened thermoplastic material in undercut areas of the arches (e.g., in embrasure areas and under fixed restorations). If necessary, the oral appliance is replaced in the hot water for approximately 15 seconds and reinserted. Care must again he taken not to allow the oral appliance to become locked into undercut areas. Once the appliance is chilled, it may be necessary to trim excess material from undercut areas. Care must be taken not to lose retention when fitting the oral appliance.

These procedures are performed until the oral appliance can inserted reasonably easily and yet has excellent retention. If retention lost because of excess reduction, it can be regained by using some of the previously trimmed thermoplastic material. This material is added back to the oral appliance, which is then replaced in hot water, and the fitting procedures are repeated. When finishing, grossly rough areas should shape with the acrylic bur; then minor irregularities can be finished using an alcohol torch. Generally, a chairside-fabricated oral appliance can be fitted, adjusted, and finished within 45 minutes.

For insertion of oral appliances that have been custom fabricated on a set of casts by a laboratory, the general technique is to heat the thermoplastic-lined oral appliance in warm or hot water. Once the thermoplastic fill material is softened according to the manufacturer's specifications, the oral appliance is inserted so that the patient's teeth seat into the custom-made indentations in the warmed and softened thermoplastic material. The patient is then instructed to bite gently into the material to ensure full seating of the oral appliance on both arches. It may be necessary to evaluate and adjust the occlusion of the maxillary and mandibular components to eliminate occlusalprematurities.

Titration of Oral Appliances

Titration of oral appliances consists of slowly moving the mandible either anteriorly or posteriorly using the adjustable mechanism until successful results are achieved with the minimum possible protrusive position. Successful results generally mean that the symptoms of the sleep disorder are eliminated or minimized to an acceptable level and any tooth or temporomandibular joint sensitivity is controlled. The titration of adjustable oral appliances may become tedious and frustrating at times and may require several weeks to months. Once completed, titration may become necessary again at some future time if sleep disorder symptoms recur or tooth or temporomandibular joint sensitivity appears. The titration process described here is for a device with a screw-type mechanism.

The oral appliance is inserted and not titrated for several days (unless discomfort presents) until the patient has become accustomed to wearing the appliance. If, as frequently happens, successful results are achieved, titration is not necessary. A lack of successful results means that the symptoms of the sleep disorder have not been acceptably addressed or that the teeth or temporomandibular joint are sensitive. If the symptoms have not been reduced acceptably, the mandible is slowly protruded, often in increments of 0.25 mm per night. After approximately 2 weeks, the patient must be re-examined if the desired results have not been achieved. Generally, this anterior movement is continued until satisfactory results are achieved. If the patient reports sensitive teeth, it may be necessary to adjust the oral appliance around the sensitive teeth. Teeth or temporomandibular joint sensitivity may also require that the mandible be slowly retruded until the problem is addressed. Once the sensitivity is corrected, it may be necessary again to protrude the mandible until the sleep disorder symptoms are addressed. Again, this procedure take weeks to months and may have to be repeated at a later date.

Recall Appointments

Recalls are necessary as a minimum, at 2 weeks, 1 month, and then every 6 months. Because many of these oral appliances are retained tightly by the remaining dentition and place almost orthodontic like forces on the teeth, frequent and timely recalls are absolutely necessary. Tooth movement is possible with these oral appliances; patients must be informed of this possibility, and developing problems must be addressed immediately. Oral appliances also become loose, distort, or break, and therefore maintenance is necessary.

Instructions during Delivery

Patients should be advised, and a consent form completed, that they may encounter any of the following:

difficulty in going to sleep, excessive salivation, chapped lips, dry throat, sore teeth, sensitive temporomandibular joints, and posterior teeth not occluding properly upon awakening. Patients must also be informed that it is possible to have irreversible tooth movement with these devices, requiring orthodontic or full-mouth rehabilitation. Many of these problems are easily addressed. The patient can have a lip balm available at bedside. Excessive salivation and the dry throat is usually a transient problem. Difficulty in going to sleep may be resolved by suggesting that the patient go to sleep without the oral appliance; when his or her snoring becomes unacceptable to the patient's bed partner, the partner should awaken the patient to insert the oral appliance. Many patients can easily go back to sleep. Sore teeth and sensitive temporomandibular joints should disappear within a couple of hours after the oral appliance is removed in the morning. If symptoms persist, the oral appliance requires immediate evaluation and possible adjustment by the clinician.

Effects of Oral Appliance

It has been thought that mandibular repositioning devices increase airway caliber to a greater extent in the retroglossal region than in the retropalatal region, because these appliances advance the mandible and pull the tongue forward. Furthermore, increases in airway caliber with oral appliances are thought to occur primarily in the anterior-posterior dimension, because these appliances increase the posterior airway space. Mechanism of action of oral appliances may be much more complex than simply pulling the tongue and soft palate forward. Advancing the mandible may put traction on the lateral walls and result in thinning of these walls.

Mandibular Advancement Splint

It was fabricated from acrylic with full both coverage in both arches to increase the mechanical pretension of the splint to the teeth. The splint was supplemented with 8 posteriorly placed SS clasps. The splint was designed with an open frontal space through the acrylin to ensure adequate respiration.

Silencor

Made of transparent, soft polyethylene material and the two bilateral connectors fixed in the region of the upper canine to lower first molar provide mechanism for the moving mandible approximately 4-8mm forward jaw opening. They are interchangeable connectors with connectors of different lengths allowing protrusive adjustment. The vertical dimension is increased by approximately 5mm by the occlusal coverage splint material Figure 17.

Figure 17: Silencor.

Karwetzky U Clasp Activator (1970)

A horizontally split functional appliance. Two 'U' shaped springs are fixed lingually to the first molar on both sides allowing mandibular protrusion to be adjusted. The alveolar part was made in hard orthodontic acrylin.

Preform Dual Laminate Mad (Chris B Johntson)

It was constructed from a bilaminateacrylin material with soft fitting surface. The appliance was fabricated by specialist orthodontic technician on stone models that were articulated using was occlusal record.

Herbst Mandibular Advancement Splint

The appliance was designed to advance the mandible by the maximum comfortable amount of protrusion possible with intermaxillary elastics to prevent any jaw opening Figure 18.

Herbst hardware variations (Rider)

a. Standard plunger type

b. The Herbst appliance

Figure 18: Herbst Advancement Splint.

The PM Positioner

PM Positioner links upper and lower splints with bilateral orthodontic expanders, has attachment connectors on both lateral sides. This appliance is made of a thermoplastic material which must be heated in hot tap water every night before it is placed in the mouth. The adjustment hardware is rigidly bound on the buccal side of the molar teeth and allows no movement of the bottom jaw while the appliance is worn Figure 19.

Figure 19: PM Positioner.

The Tap-Thornton Adjustable Positioner

This appliance allows for progressive ¼ mm advancements of the jaw via an anterior screw mechanism at the labial aspect of the upper splint. This is an appliance which has a separate section for mandibular and maxillary. Each portion of the appliance is placed the mouth separately and then the patient sticks out his/her chin until the ' hook and bar' hardware can be connected. The hardware is located at the tip of the tongue, and may take some getting used to. The adjustment knob sticks out through the lips and is visible when sleeping. This appliance is easily retained by tooth grinders, even those who have worn away much of their tooth structure Figure 20.

Figure 20: Thornton Adjustable Positioner.

The Ema Elastic Mandibular Advancement

This appliance design uses specially designed, patented elastic bands to reach the desired position with considerable freedom of movement. The E.M.A. is the thinnest and least bulky of all the appliances. It is similar to clear acrylic orthodontic retainers, and moves the jaw forward in fairly significant steps, and can be difficult to tolerate

OPAP: 'Oral Pressure Appliance'

It is a "combination" therapy which combines a nonadjustable MRD with continuous positive airway pressure (nCPAP). Instead of using nasal nCPAP, which delivers air pressure through a mask over the nose or the nose and mouth, the air pressure is delivered through a small conduit that fits across the roof of the patient's mouth. Thus, the more effective nCPAP can be used by patient without the need to wear a nasal mask, have elastic straps around the head, or sleep on one's back. Pressures necessary to control snoring and obstructive sleep apnea are much lower when delivered through OPAP than when using nasal delivery Figure 21.

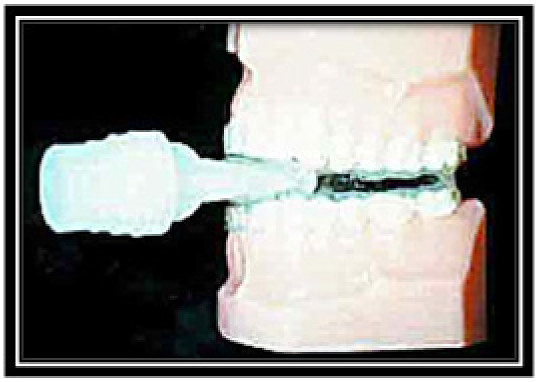

Figure 21: Oral Pressure Appliance.

Mandibular Advancement Appliance (MAA)

MAAs enlarge and stabilize the oro- and hypo-pharyngeal airway space by advancing the mandible, and stretching the attached soft tissue, and in particular the tongue. A tooth-borne device and a modified activator have been reported to reduce snoring and to improve the incidence of OSA. In a prospective computerized tomographic study, Gale et al. (2000) showed that there is a wide and unpredictable intra-individual variation in the response to mandibular advancement. When comparing differently designed oral appliances in various patient groups, the results may reflect differences between the groups, e.g. due to intra-oral and pharyngeal anatomy, rather than between appliances.

With treatment success based on RDI reduction alone, improvements of 66 per cent (Karwetzky activator) and 53 per cent (Silencor) were measured; these success rates are thus similar to those of other, comparable designed appliances. This difference in treatment success might be due in part to the design characteristics of the appliances, since the materials and the rate of retention differed.

Fabrication of Appliance

It is constructed of a temperature-sensitive acrylic resin that is slightly soft at body temperature and very compliant at higher temperatures. This decreases tooth discomfort but also considerably increases retention. The adjustable mandibular advancement appliance also permits lateral and vertical jaw movement during sleep to reduce the risk of temporomanibular joint and jaw muscle discomfort. Full-tooth surface coverage reduces the possibility of any occlusal change Figure 22.

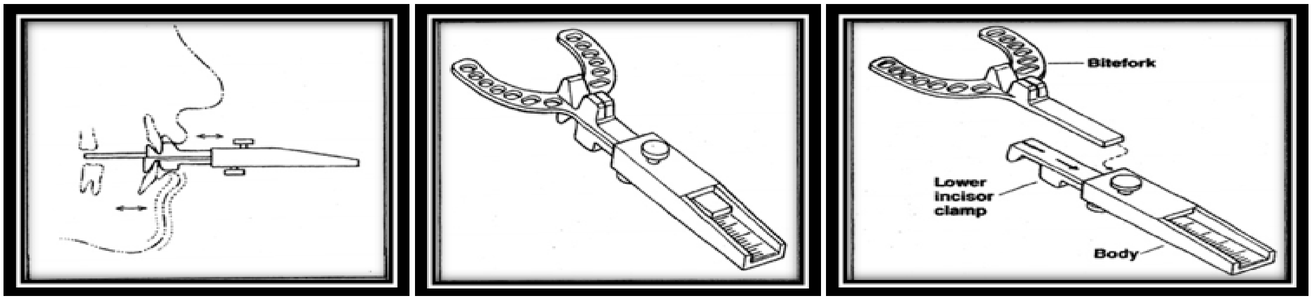

Figure 22: Adjustable Mandibular Advancement Device.

An initial bite registration was taken at two thirds of the maximum protrusive position. The George guage overestimated the maximum range of protrusion compared with the ruler measurements. Minimum vertical separation between maxillary and mandibular incisors was obtained. An adjustment period followed the insertion of the appliance during which the advancement was continued until relief or maximum reduction of snoring and reported apnea.

Indications

a) Mild to moderate OSA and patients who do not exceed 125%-150% of their ideal body weight.

b) UARS with snoring and mild OSA

c) Retrognathia

d) Failed other modalities of treatment especially effective if UPPP did not bring down RDI to an acceptable level

e) Patients who do not agree for surgery.

f) Patients who are medically compromised, or elderly or who cannot afford surgery.

g) Patients who are non-compliant with CPAP.

h) Patients who are mouth breathers or nose breathers

i) As a diagnostic tool prior to maxillo-facial surgery

Contraindications

a) Severe periodontal disease

b) Existing temporomandibular joint disease (arthritis etc.)

c) Painful masseter muscles

d) Incomplete dentition which compromises retention of the appliance

e) Atrophic edentulous ridges as evidenced by poor denture retention

f) Severe hypoxemia

g) Severe OSA

h) Growing children

i) Protrusive range of mandible < 7 mm

j) Ability to open interincisally 30 + mm

k) Unmotivated patients

l) Morbidly obese NC <20”or weight over 300 lb. for men. NC over 17” for women. (Lowe) obese pts are less compliant with OA use (patients are found not to respond well to OA therapy if more than 150% ideal body weight because obesity limits pharyngeal airspace, increasing obstruction)

m) Central sleep apnoea

Uses of MAA (Mandibular Advancement Appliance)

Airway change

PAS (Posterior Air Space) did not always increase on cephalometric studies with the MRD device in place. Rick Schwab’s work shows lateral increase of up to 25% retroglossally and 16% retropalatally. Awake Fiberopticvideo endoscopy showed no alteration in hypopharynx or oropharynx, but a significant increase in x-sect. of velopharynx. MRI evaluation with MRD in place showed 32% total increase in volume with the largest improvement in the airway behind the mid-soft palate and uvula/ nasopharynx area Decrease in MP/H shown by multiple appliances.

Sleep Change

a) A 39% relative decrease in stage 1 sleep (Clark / Herbst)

b) Increases in stage 2, 3, 4 and REM sleep (Clark / Herbst)

c) REM sleep increased 50%.

d) The average total sleep time increased by 23 minutes Total sleep time was unchanged (Menn) Arousal Index decreased significantly

e) Sleep efficiency improved from 80% to 86% (Menn)

Apnoea Change

1) 70% of pts show a 50% decrease in RDI (Schmidt-Nowara, et al. ASDA Review) 56% returned to normal breathing (RDI below 10/hr).
2) Review 1995: AI decreased 54.3% RDI decreased 53.8%.
3) Arterial oxygen saturation increased in 75% of the patients and O2 nadir from 78% to 86% (Menn).
4) The initial rate of complete airway obstruction decreased 10.1 events/hour and partial airway obstructions decreased by 9.07 events/hour.
5) MRD devices showed a reduction of apnoeic events in patients with OSA as well as central apnea. There was no change in the amount of time spent in mixed apnea. Yoshida reported a slight increase in central apneas and a decrease in mixed and obstructive apnoeas .Some studies claim 60% success rate (RDI <10) in moderate and severe OSA.

Symptom Change

1) Patients reported a decrease in snoring, increased alertness and some reduction in daytime sleepiness (subjectively).
2) Snoring reduced >50% in 87% of pts. (Schmidt-Nowara review).
3) Appliances become more effective with time, possibly due to the resolution of edema.

Anatomic Repositioning

1) Opening of the airway, especially in the lateral aspects of the PAS (25% hypoglossally, 16% retro palatally) (Ferguson or Schwab). Opens all 3 areas of pharynx (Evaloff) Statistical invelopharyngeal area only.
2) The tongue advances. Tongue is placed more superiorly and the dorsal aspect of the tongue becomes narrower and moves superiorly, the hyoid moves more anteriorly.
3) Thinning of the lateral walls of the pharynx occur as the tension increases on the soft palate.
4) Clockwise rotation of the mandible and passive opening of the vertical dimension activates the genioglossus muscle effecting changes in the shape of the tongue. Lowe's animal studies demonstrated that the increased gg muscle activity remains relatively constant as long as the OA is in place [73].
5) A stable anterior position of the mandible and tongue which prevents posterior relapse of the mandible and tongue during sleep.
6) Mandibular protrusion and concomitant tongue repositioning might modify the position and function of the soft palate by virtue of its attachment to the base of the tongue- as seen in two studies where PNS-P (length of the soft palate) was reduced with the appliance in place.
7) Hyoid moves anteriorly in successful cases.
8) CT and MRI imaging confirm the expectation that MRDs designed according to currently accepted treatment protocols cause the mandibular condyle to translate a significant distance out of the glenoid fossa, even as far as the articulator eminence.

Stabilization

1) Mandible is stabilized in position.
2) An oral airway appliance may alter pressures in the oropharynx so as to reduce narrowing and collapse during inspiration [74].
3) Prevention of wide mandibular opening prevents the mandible from rotating backwards and the base of the tongue obstructing the airway.
4) Prevention of opening the mandible inactivates the 'anti-tongue biting' reflex which causes the tongue to retract. Passive or active opening activates afferents in TMJ that reflexively inhibit the genioglossus muscle, making the tongue more vulnerable to negative pressure in the airway.

Increased Muscle Tone

1) Increase genioglossus muscle activity.
2) Increased tonicity of the genioglossus muscle related to mandibular protrusion and increase in vertical dimension. This may counteract the loss of muscle tone experienced during stage 3&4 non-REM and REM sleep.
3) OA may stimulate receptors in the UA to increase airway tone.

Dental effects: Significant retroclination of the maxillary incisors and proclination of the mandibular incisors were accompanied by reductions in maxillary arch length, overbite and overjet. The SNA, ANB angles, ANS–PNS length and face height increased, and the mandibular first molars and the maxillary first premolars significantly over-erupted. The appliance used produced small, changes in the occlusion that tended to occur after 24 months wear. It is postulated that the changes in overbite might be lessened by keeping the bite opening to a minimum. Minor dental changes might be an acceptable side effect, if associated with significant treatment efficacy. In cases of unacceptable, progressive occlusal alterations, the indication for therapy with an OA has to be re-evaluated, and, in severe cases, therapy might have to be changed to CPAP [75] Figure 23.

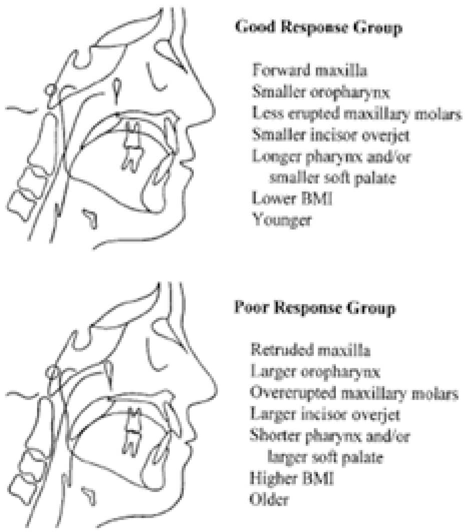

Figure 23: Summary of Cephalometric and Demographic Characteristics of OSA Patients with Good and Poor Responses to MAA Based On Stepwise Regression Equation.

Mad With Lower Control Plate (Mebta and Coworker)

It is a custom made adjustable MA splint to a lower control plate with no protrusive effect. Two separate, full coverage, hard acrylin splints was fabricated each 1.5 to 2 mm thick, so as to minimize the vertical bite opening. The upper splints had bilaterlal flanges extending inferiorly from the palatal aspect of the molar region. These flanges engaged slots in the lingual molar area of the mandibular splint and the used expansion screws to provide incremental mandibular advancement.

Hard Acrylic Splint With Bilateral Buccal Flange (Gotsopoulos,Chen)

Two separated hard acrylin sprint were fabricated each 1.5 to 2mm thick so as to minimize the vertical opening. The lower portion, with bilateral buccal flanges extended in a superior direction in the molar region and abutted against bilateral expansion screws anchored in the upper appliance.

Nocturnal Airway Potency Appliance (Nada)

It was designed to keep the airway open during sleep by

a) Posturing the tongue more anteriorly
b) Inhibiting wide jaw opening
c) Assuring adequate air intake through the mouth whenever nasal obstruction exists. It is constructed wire and acrylin. It stabilizes the mandible in bone horizontal and vertical dimensions with clasps on the four first molar and with overlapping acrylic on the facial and lingual surfaces of all teeth.

Functional Magnetic System

Type1: The functional magnetic system is a mandibular repositioning appliance that uses a pair of attractive magnets (Sm¬2CO17) placed opposite each other in the jaws which results in advancement to opening ratio of 1:2. It operates by increasing the anterior region of the oral caving, mainly vertically with no change in the posterior oral cavity region and pharyngeal airway passages.

Type2: Two intraoral removable occlusal splint vita full tooth coverage, one in the maxilla and one in the mandible. The total height of two splitting together was between 14 mm and 18 mm. The plane between the splints was inclined sagittally 100 to 150 to produce on oblique force vector for favoring forward advancement of the mandible. Four propylene coated (poly-para-xylene 250mm) neodymium - iron - born magnets (Nd2 Fe14 B, Size 6.4 mm x 2 mm)

Monoblock Mandibular Advancement Splint (Lors Bondemark)

It was fabricated from acrylin with full tooth coverage in both arches. To increase the mechanical retention of the splint to the teeth, the splint was supplemented with potentially placed SS clasps. Splint was designed with an open frontal space through the acrylic to ensure adequate retention.

AMPA (Anterior Mandibular Repositioning Appliance)

It consists of pair of 3 mm thick polyetheleneocclusal coverage splints constructed from Erkoflex 82 material and heat welded together. It brings about the anticlockwise movement of mandible, thus brings the mandible forward.

Klearway Splint

The Klearway oral appliance, which utilizes a maxillary orthodontic expander to sequentially move the mandible forward. Klearway is a fully-adjustable oral appliance used for the treatment or snoring and mild to moderate Obstructive Sleep Apnea. Fabricated of thermoactive acrylic, Klearway TM becomes pliable for easy insertion and confirms securely to the dentition for an excellent fit while significantly decreasing soft tissue and tooth discomfort. Small increments (25 mm) of forward lower jaw advancement are initiated by the patient under the direction of a dentist and this helps avoid rapid jaw movements that can cause significant patient discomfort. Once warmed under hot water and inserted, the acrylic resin hardens as it cools to body temperature and firmly affixes itself to both arches. Lateral and vertical jaw movement is permitted which enables the patent to yawn, swallow, and drink water without dislodging the appliance Figure 24.

Figure 24: Klearway Splint.

Twin Block

The use of functional appliances for the correction of retrognathic mandible is very common in orthodontics. Similar appliances known as oral appliances are also frequently used in adults for the treatment of mild to moderate obstructive sleep apnea (OSA). Many studies have reported improvement of pharyngeal airway passage (PAP) dimensions following functional appliance therapy in children and oral appliance therapy in adults. There is only one study in the literature that discussed the effect of oral appliance therapy on posterior pharyngeal wall thickness (PPWT) among subjects with OSA. Correction of mandibular retrusion in class II malocclusion subjects by twin-block appliance increased the sagittal dimension of the oropharynx and hypopharynx. The length, thickness, and inclination of the soft palate improved following correction of mandibular retrusion in class II malocclusion subjects. The correction of mandibular retrusion by twin-block appliance in class II malocclusion subjects had no significant effect on the posterior pharyngeal wall thickness Figure 25.

Figure 25: Change in Pharyngeal Airway after Twin Block Therapy.

The above cephalometric parameters and reference points shows the change in pharyngeal airway after treated with Twin- Block. The appliance is found useful in treating patients of Class II malocclusion with Retrognathic mandible having OSA.

Predictors of Success with Oral Appliances

a) One cannot predict the potential success of OA treatment based on anatomic consideration alone. Success has been variously defined by various investigators, but OA researchers now tend to use the same criteria as CPAP researchers: i.e. the RDI must drop by 50% from the baseline RDI AND end below. (Some accept 15 as a therapeutic RDI).

b) Less successful if soft palate length is over 48 mm, Responders avg. soft pal. 44mm, non-responders avg. 50 mm (Bonham).

c) OA therapy is more successful if mandibular plane angle is normal and the lower face height is smaller. (Bonham).

d) Baseline MP-H smaller (Eveloff found the MP-H base in responders was 23degrees and1 mm vs. 28.6 degrees and 1.5 mm).

e) Appliance shortens soft palate (Evaloff) found baseline PNS-P didn't vary between responders and non responders, but with the appliance in place, responders had a shortened PNS-P of 41mm vs. 47mm.).

f) Responders have a lower BMI vs. non-responders (Lowe) OA responders, in 1 study, had baseline RDI <10, partial responders RDI < 20 NB: There is no placebo effect with an oral appliance. The mandible MUST be advanced for a positive effect with an MRD.

g) BMI and cephs are not predictive of success (Menn).

Surgical Treatment

Historically, surgical procedures for OSA treatment have included intranasal procedures, reduction glossectomies, uvulopalatopharyngoplasty procedures, and tracheostomy.

Disadvantage: The pain and expense of the surgery and the relatively poor long-term success rate because the obstruction is often present at multiple levels.

Uses

a) Surgery may be appropriate for patients who cannot comply with or are not appropriate candidates for conservative therapies or CPAP alone. The type of surgery performed should be based upon the specific pathophysiology of a patient's condition.

b) **Syndromic patients:** Careful and thorough preoperative examination by radiography, imaging, and direct visualization is needed to identify the airway obstruction sites and to select the appropriate surgery.

Evaluation of Upper Airway

The upper airway begins at the nose and lips and ends at the larynx. Pre-surgical evaluation must include the entire upper airway to determine the most likely region of collapse and obstruction and to direct proper surgical intervention to these anatomic sites. The principal methods of the evaluating the upper airway include complete head and neck physical examination, lateral cephalometric radiographs, and nasopharyngeal laryngoscopy with a flexible endoscope. There are two main objectives for examination: first, to rule out any other pathology causing sleep-disordered breathing and second, to isolate the anatomic sites of obstruction. Multiple sites may be involved in the obstructive process. The upper airway can be divided into three main regions for evaluation: the nose and nasopharynx, the oral cavity and oropharynx, and the hypopharynx and the larynx. Pathologic entities such as neoplasms, cysts, and other masses, OSA patients often present with disproportionate anatomy, consisting of a large soft palate, uvula, and base of tongue and a hypoplastic mandible. The three major areas of obstruction are the nose, the palate, and the hypopharynx. Frujita described these areas of collapse as retropalatal (type I), retrolingual (type III), retropalatal or retrolingual (type II) [76].

Tracheostomy

A Tracheotomy is one of the oldest, most shunned, and least understood procedures for OSA. The concept with this procedure is that any area of blockage to breathing, from the nose to the voice-box, is bypassed by a hole placed into the windpipe. The tracheotomy tube must be kept exquisitely clean; otherwise, painful infections will occur, or the tube and/or windpipe could become blocked with secretions. Tracheotomy is 100% effective in alleviating OSA by bypassing all up obstructive sites. This procedure is usually reserved for the most severe OSA patients; patients are reluctant to receive a tracheotomy because of poor patient and social acceptance. Nonetheless, tracheotomy is a useful procedure to alleviate immediate obstruction and provides excellent airway control until other surgical procedures can be safely done. Patients with cardiac abnormalities (e.g. arrhythmias), oxygen saturations below 50%, and morbid obesity (body mass index [BMI] >33 kg/m2) Figure 26.

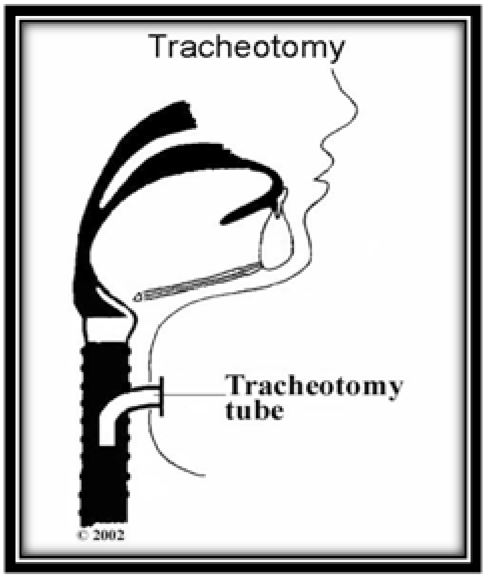

Figure 26: Tracheostomy.

Uses

When OSA is severe and CPAP is not tolerated or ineffective or cardio-pulmonary failure has developed then a tracheotomy may be the initial treatment of choice. A month or two later a sequence of procedures can be initiated as indicated. If the sleep study showed resolution of the OSA then formal plans could be made to remove the tracheotomy tube and allow the stoma to be closed. Few patients (e.g those who have severe heart failure or severe pulmonary disease, who cannot tolerate CPAP, and for whom other measures failed) require tracheostomy. Permanent tracheotomies are provided for patients requiring lifelong upper airway bypass for severe OSA with medical compromise or entities such as bilateral vocal cord paralysis, amyotrophic lateral sclerosis, or myasthenia gravis.

Nasal Airway

Although the major sites of collapse and obstruction of the upper airway lie in the retropalatal and retro lingual regions, the nasal airway can have a tremendous effect on the collapse of these sites. The nasal airway has a unique function in providing a level of resistance for the upper airway, which optimizes alveolar gas exchange, including recovery of heat and water vapour [77]. Septal deviations, turbinate hypertrophy, and polypoid disease can correct with septoplasty, turbinate reduction, and polypectomy, respectively. Adenoid obstruction of the posterior choanae is improved adenoidectomy. Chronic sinusitis refractory to medical therapy may require sinus surgery to re-establish proper sinonasal drainage and ventilation.

Nasal, Septal and Adenoid Surgery

Weak or malpositioned cartilages around the nostrils can impede nasal breathing as will a droopy nasal tip or excessively narrow nostrils. The nasal turbinates may become chronically enlarged usually as a result of allergies. Reduction in the size of the turbinates will improve nasal air flow. If the septum is crooked, it may cause blockage of the nasal breathing passage. It is corrected by septoplasty [78]. An enlarged adenoid may occasionally interfere with breathing. An adenoidectomy removes this excess tissue to allow for unrestricted airflow through the nasal passages and upper throat. Surgical improvement of the nasal valve may be accomplished with spreader grafts placed between the septum and upper lateral cartilage by clever suturing of the upper and lower lateral cartilages. Other structural grafts, including alar, tip rotation, and upper and lo lateral cartilage grafts, can also provide support to the nasal airway.

Tonsillectomy

The removal of redundant tissue by tonsillectomy increases the caliber of the pharynx thereby reducing blockage to breathing. Since the quality and quantity of tissue of the throat changes after tonsillectomy there can be a subtle alteration in voice quality. In a mature adult, pain following tonsillectomy can be unpleasant, but is reasonably well controlled with prescription medication [79] Figure 27.

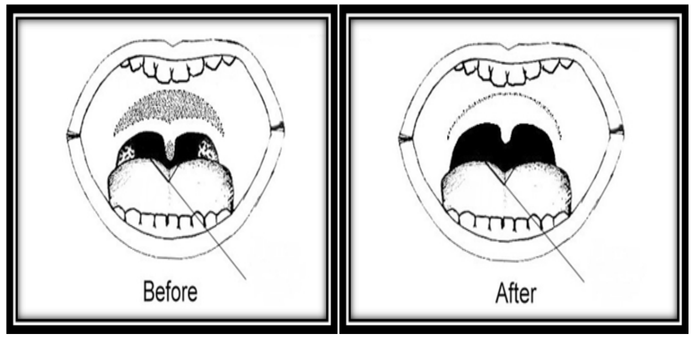

Figure 27: Reduced Airway blockage after Tonsillectomy.

Genioglossus Tongue Advancement

The procedure is done through an incision below the gingiva in front of the mandibular anterior teeth. After creating a small rectangular bone window, the tendons that attach the tongue to the jaw are pulled forward on a small bone fragment. This produces a larger space between the back of the tongue and the throat thereby creating a wider airway. There is minimal if any alteration in facial appearance. This operation is often performed in tandem with at least one other procedure such as the UPPP or hyoid suspension Figure 28.

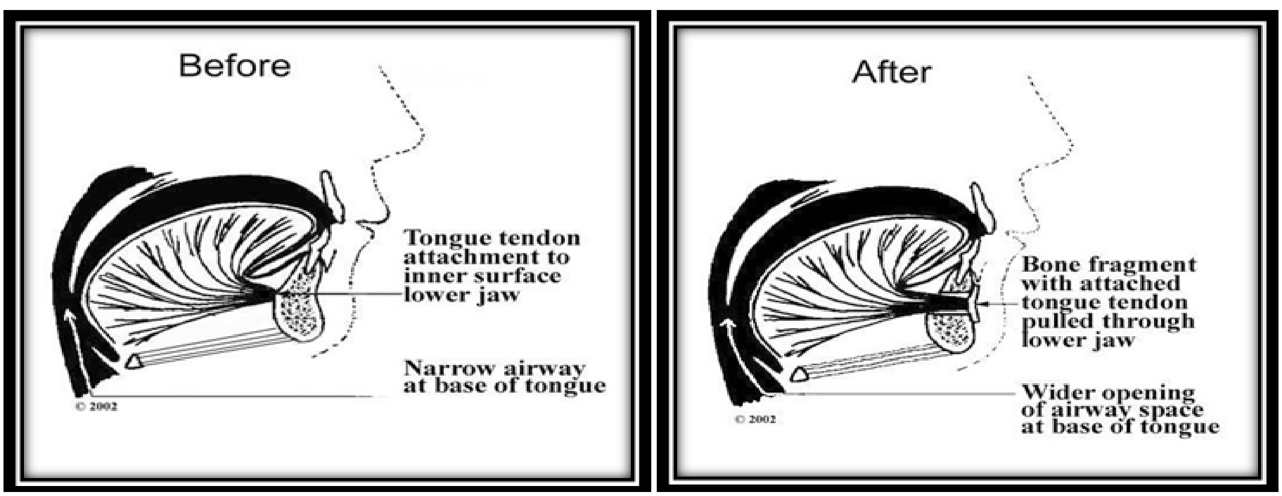

Figure 28: Change in Pharyngeal Airway after Tonsillectomy

Uvulopalatopharyngoplasty (UPPP)

Uvulopalatopharyngoplasty (UPPP) is designed to decrease oropharyngeal collapsibility by reducing the soft palate, uvula, posterior and lateral pharyngeal walls, and tonsils when present. The criteria for success are a 50% reduction of the respiratory disturbance index (RDI) or apnea-hypopnoea index (Ahi), with an ultimate RDI reduction below 20. The UPPP is a single-stage technique carried out in the hospital with at least an overnight stay to observe for increased swelling and possible exacerbation of the OSA [80] Figure 29.

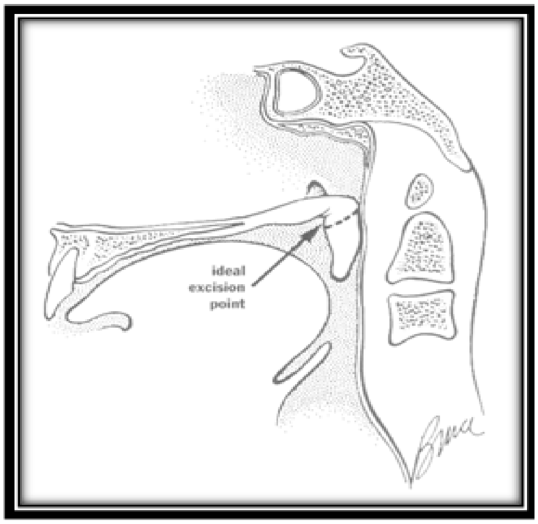

Figure 29: Site of Performing Uvulopalatopharyngoplasty.

Complications may include temporary or permanent velopharyngeal insufficiency, infection, nasopharyngeal stenosis, hemorrhage, airway loss, speech and taste disturbance, decreased ability to clear pharyngeal secretions, and a sensation of pharyngeal dryness.

Laser-Assisted Uvulopalatoplasty

Laser-assisted uvulopalatoplasty (LAUP) was initially introduced for snoring by Kamami in 1990. This office procedure is usually staged over several visits, allowing healing for at least 6 weeks between treatments. Laser-assisted uvulopalatoplasty has shown a good success rate of approximately 85% for snoring. This success has led to the use of this technique for OSA. Many of the studies concerning LAUP for OSA have been conflicting; however, most of the LAUP successes for OSA have been in patients with an RDI below 30. The procedure is accomplished in the office with local anaesthesia. Full-thickness cuts are made on both sides of the uvula followed by reduction of the palatal arch lateral to these cut. Laser-assisted uvulopalatoplasty (LAUP) Like UPPP, LAUP may decrease or eliminate snoring but not eliminate sleep apnea itself. To identify possible underlying sleep apnea, sleep studies are usually required before LAUP is performed. The gallium aluminium arsenide infrared P-laser (830 nm) has been used [81] Figure 30.

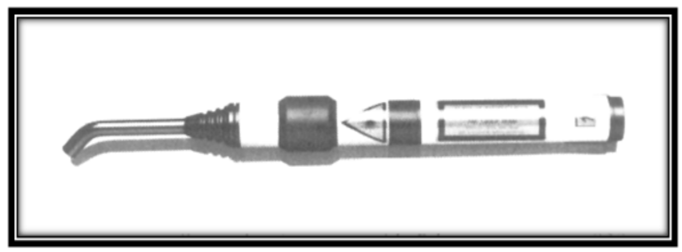

Figure 30: Gallium Aluminium Arsenide Infra P –Laser.

It is non-invasive and non-destructive to tissues, but it has an anti-inflammatory and hypo analgesic effect, along with producing increased tissue healing in animal experiments. LAUP is about 85% effective in muting snoring and 65% effective in improving apnoea Figure 31.

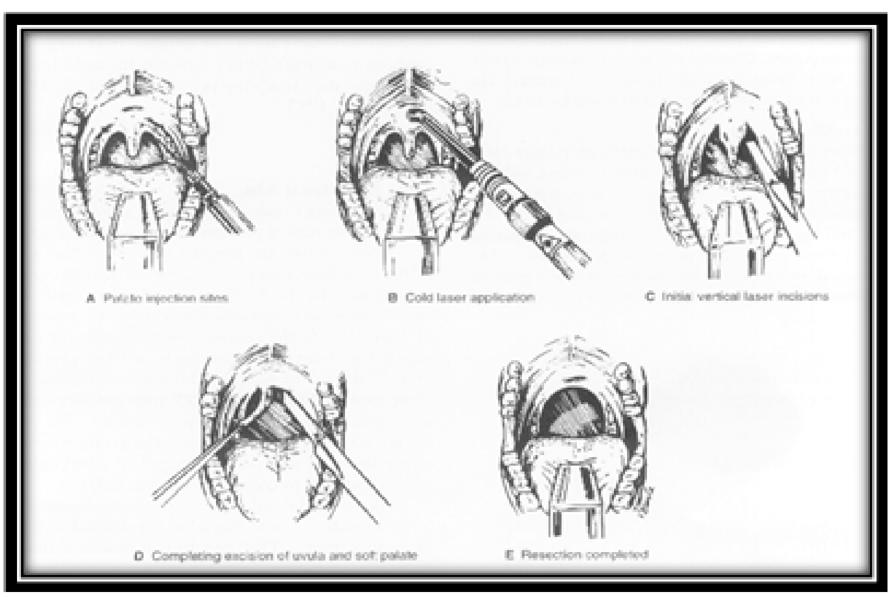

Figure 31: Laser Assisted Uvulopalatoplasty.

The potential complications for the LAUP include a sensation of thick mucus in the throat, taste alteration, decreased oropharyngeal transit time, phonation changes, hemorrhage, velopharyngeal insufficiency, and nasopharyngeal stenosis.

Radiofrequency Volumetric Tissue Reduction of the Soft Palate or Somnoplasty

Radiofrequency volumetric tissue reduction (RVTR) of the palate is currently indicated only for snoring patients with an RDI of less than 15. This procedure is carried out in the office with local anaesthesia. The energy is delivered to the palate in the midline and each side laterally with a custom-designed hand piece connected to a radio frequency generator (Somnus Medical Technologies, Sunnyvale, CA). A lesion is formed in the palate which results in coagulative necrosis and contraction, resulting in a volumetric reduction and stiffening of the soft palate. The efficacy of this treatment for snoring may approach 85% after two or more treatments 6 weeks apart to allow healing and appropriate evaluation before the next treatment [82].

Procedure

The radiofrequency treatment involves piercing the tongue, throat or soft palate with a special needle (electrode) connected to a radio frequency generator. The inner tissue is then heated to 158F to 176F, in a procedure that takes approximately half an hour. The inner tissues shrink, but the outer tissues, which may contain such things as taste buds, are left intact. During the following six to eight weeks the submerged wound undergoes healing, contraction and stiffening Figure 32.

Figure 32: Custom designed Radio-Frequency Device.

Advantages

Somnoplasty is performed under local anaesthesia in an outpatient setting. In contrast to conventional surgery, during somnoplasty we are able to protect the delicate surface of the tissue, control the delivery of energy and maintain a constant, low temperature, features that result in far less post-operative discomfort. While people undergoing traditional surgery can suffer significant pain and take narcotic medications for several weeks, individuals undergoing Somnoplasty usually experience swelling and some discomfort, and take pain medications for two to three days [83].

Postoperative complications are significantly less than those for UPPP and LAUP, and there is virtually no risk of velopharyngeal incompetency, nasopharyngeal stenosis, dysphagia, or phonation changes. It requires significantly more treatment sessions.

Effectiveness of Somnoplasty

Initial clinical results showed that Somnoplasty effectively treated OSA by shrinking the base of tongue - the most difficult source of obstruction to treat. Clinical efficacy of the Somnoplasty treatment for turbinate hypertrophy published by Li, et al. reported that 95% of the subjects studied had improvement in their nasal breathing at 8 weeks post procedure Figure 33.

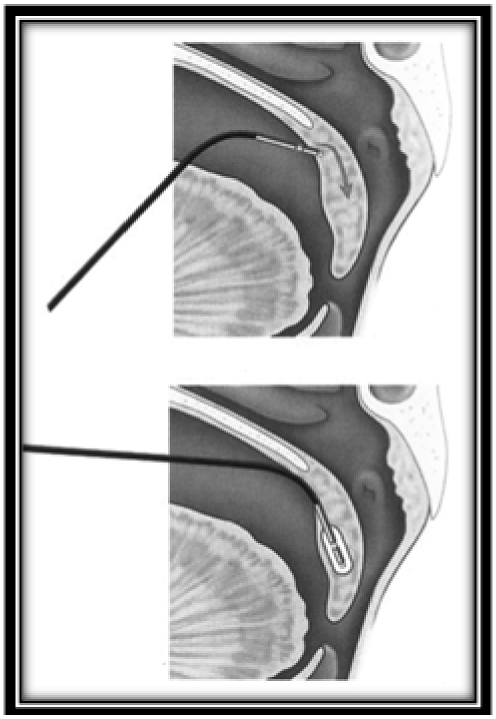

Figure 33: Change in Airway after Somnoplasty.

Hyoid Myotomy and Suspension

The purpose of a hyoid myotomy and suspension (HMS) procedure is to alleviate the redundant lateral pharyngeal tissue or retro displaced epiglottis. The hyoid body is dissected in the midline, and the inferior muscle attachments are released. The suprahyoid muscles are left intact, although occasionally the stylohyoid ligament is sectioned from the lesser cornua to allow adequate mobility. The hyoid bone is then suspended over the thyroid ala and secured with two permanent medial and lateral suture. Complications may include damage to the superior laryngeal nerve, dysphagia, a sensation of a tight throat, transient aspiration, and hyoid fracture [84] Figure 34.

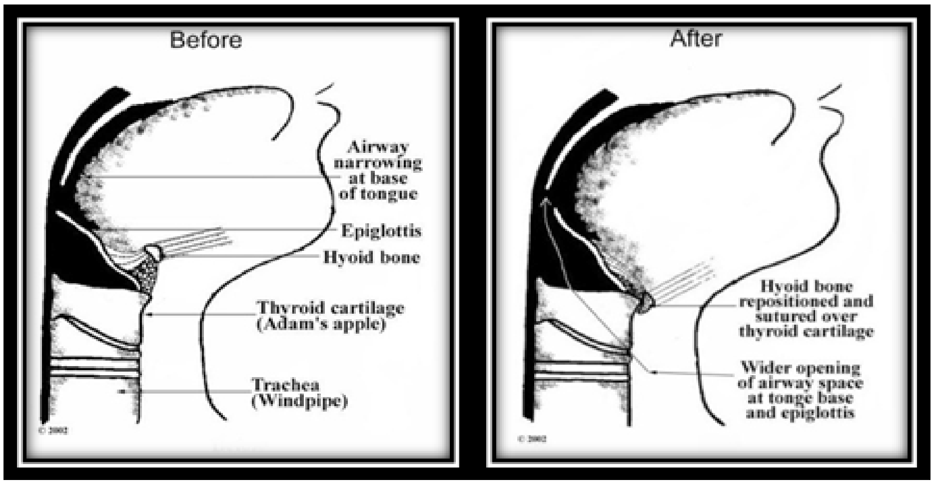

Figure 34: Changes in Pharyngeal Airway after Hyoid Myotomy.

If the hyoid bone containing suprahyoid muscles is pulled forward in front of the voice box, it can open the airway space behind the tongue.

Advantages

This is performed under local intravenous sedation or general anesthesia, and requires a one or two day hospital stay. Since the vocal cords are not manipulated, the voice should remain unimpaired.

Maxillomandibular Osteotomy and Advancement

Maxillomandibular advancement (MMA) anteriorly repositions the maxillary and mandibular framework and their attending muscular attachments. This procedure addresses the retropalatal and retro lingual regions, provides additional tension for the genioglossus muscle, and increases the available room in the floor of the mouth for the tongue. An MMA is the most effective surgical treatment for OSA other than tracheotomy, and success rates approach 100%. Furthermore, MMA may be considered as the primary treatment for OSA when diffuse complex or multiple sites of disproportionate anatomy exist in the oral and hypopharynx.90The maxillary surgery is a standard LeFort I osteotomy which is advanced 10 to 14 mm and stabilized with rigid internal fixation. Bone grafts are required to fill in the gaps created by the large advancement. The mandible is advanced 10 to 14 mm by a bilateral sagittal split osteotomy and stabilized with rigid internal fixation with bicortical screws. Additional maxillomandibular skeletal fixation can help prevent skeletal relapse.

Mandibular Osteotomy with Genioglossus Advancement

The tongue (genioglossus muscle) attaches to the geniotubercle on the posterior aspect of the anterior mandible. A rectangular osteotomy around the geniotubercle is accomplished on the labial surface of the anterior mandible. It is desirable to leave 8 to 10 mm of inferior border to decrease the chance of fracture. Ideally, the superior incision is made 5 mm below the root apices [85]. The genial segment with its genioglossus attachment is advanced, rotated, and rigidly fixed to the mandible. This advancement provides tension to the tongue, preventing posterior collapse. This procedure may provide some increased retro lingual space but does not increase space for the tongue. Complications include fracture, bleeding, and damage to teeth.

Midline Glossectomy

Laser midline glossectomy is accomplished by vaporizing a 2.5-cm by 5-cm rectangular portion of the midline tongue with a laser. A lingual tonsillectomy, reduction of aryepiglottic folds, and a partial epiglottectomy can be done concomitantly, if indicated. A tracheostomy is needed in the immediate postoperative period because of the large amount of edema following tongue reduction include bleeding, prolonged dysphagia, and altered taste.

Linguloplasty

The linguloplasty differs from the laser midline glossectomy in that the excision is extended more posteriorly and laterally. The defect is closed by suturing the posterior margin anteriorly, which advances the tongue base anteriorly. The anterior rotation of the posterior margin significantly improves the success rate to around 77%. Again, this procedure is usually combined with a tracheotomy.

Radiofrequency Volumetric Tissue Reduction of the Base of the Tongue

Radiofrequency volumetric tissue reduction of the tongue base is approved for the treatment of OSA. The preoperative mean RDI of 39.6 decreased to a mean of 17.8 following treatment of the tongue.

Tongue Base Suspension Sutures

For tongue-base suspension sutures, a non-absorbing suspension suture is placed into the tongue and then is attached to a titanium bone screw inserted into the genioturbucle of the posterior aspect of the mandible (Jnflu-ENT Company, San Francisco, CA). The suture tension prevents posterior tongue displacement and occlusion with the posterior pharyngeal wall. Although minimally invasive, the procedure is accomplished under general anaesthesia or local anaesthesia with intravenous sedation. Postoperative morbidity, pain, and complications are minimal. Relative contraindication would include marked macroglossia and severe tongue grooving.

Conclusion

Obstructive Sleep Apnoea is a common respiratory disorder characterized by recurrent upper airway Obstruction during Sleep. Chronic persistent snoring is common symptom that increases in prevalence throughout the lifespan, with well over 50 percent of the individuals reporting it over 60 years of age. Normal respiration requires that air be displaced from the external environment into the lungs, where it can contact the alveolar membrane to make oxygen available for gaseous exchange with the blood stream. The ostensibly simple function of upper airway is to permit the unimpeded movement of humidified air to the tracheobronchial tree. Apnoea results from complete or partial interference with this process.

The most commonly encountered impedance of airway is upper airway obstruction, which is most often secondary to morphologic, pathologic or functional abnormalities of the upper airway. Supralaryngeal airway is very susceptible to Obstruction elicited by hypotonicity associated with sleep, and the most obvious manifestation of such upper airway obstruction is snoring. Although snoring has been the subject of countless humorous literary references, it a medical enigma that is now well recognized as an important sign of the potentially lethal condition that we call OSA, Obstructive Sleep Apnoea. It has been seen that Snoring can range from entirely benign condition to serious Cardiopulmonary and behavioural sequelae. The most common initial complaints in sleep apnoea are excessive daytime sleeping hours, irritability, depression and snoring. In some instances patient may also present with the cardiac involvement. Snoring should always be suspected in an individual with a history of loud snores combined with any of these symptoms. Snorers may also exhibit other type of breathing disturbances such as disruption of the central nervous system stimuli that initiate a breath. This differs from OSA in which breath is initiated but air exchange cannot occur because air movement is blocked by collapse or other blockage of throat

Treatment of sleep apnoea can reduce snoring dramatically. However even a dramatic reduction of snoring may not necessarily result in improvement in alee apnoea, so careful monitoring is essential.

Oral appliances are a treatment option in the management of sleep apnoea syndromes. While many patients experience a complete or partial resolution of their symptoms, some do not improve or may even become worse. It is therefore imperative that physicians conduct progress evaluations while the respective dental care provider continues to make adjustments to optimize the effectiveness of the chosen appliance. Since the first nonadjustable, hard acrylic appliances were developed to treat OSA, a variety of removable devices have been designed to provide improved patient comfort and hence, hopefully, patient compliance. The trend has been toward adjustable devices, while the materials now are being used to construct mandibular protrusion devices include heat-softening acrylics and plastics with soft liners. It should be noted, however, that in a recent randomized trial, patients preferred a single-piece Monobloc appliance to a continuously adjustable. Herbst constructed of the same that hard acrylics are necessarily more uncomfortable than heat-softening acrylics and plastics with soft liners.

Future research will help to identify the types of patients who are suitable for a specific kind of OSA treatment.

Acknowledgement

With the grace of almighty, I am making this small contribution towards society regarding the most important aspect of Mordern Dentistry called Obstructive Sleep Apnoea. This small handbook has been developed as a basic guide regarding this particular topic. This is my first handbook and I am grateful to my teachers and colleagues especially Dr Ish Kumar Sharma who had been supporting me through all the time of research. I would like to express my gratitude to my professor Dr P Narayan Prasad, my guides Dr Tarun Rana and Dr Tarun Sharma for all their dedication and support. I would also like to appreciate my parents Mr Nazir Ahmed Ronga and Mrs Bilkies Ronga, my siblings Uzair and Umair for believing in me and for the never ending support and love. Special thanks to Medwin Publishers for considering my efforts and for emence co-operation. I dedicate this book to my Grandfather Dr Mohammed MaqboolBhat. Thank you one and all.

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