Republic of Iraq
Ministry of Higher Education
And Scientific Research
University of Baghdad
College of Dentistry

Upper airway and cranial morphology

(A review study)

A Project Submitted to
The College of Dentistry, University of Baghdad, Department of Orthodontics in
Partial Fulfillment for the Bachelor of Dental Surgery

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May, 2023

Certification of the Supervisor

I certify that this project entitled "**Upper Airway And Cranial Morphology**" was prepared by the fifth-year student **Teeba Zuhier Kamil** under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

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May, 2023

Dedication

To **My Mother**

To the strongest woman that I know my lovely mom, who taught me to trust .Allah , believe in hard work and gave me all the support and love

To **My Father**

My dad the reason why I’m here, he encouraged me to be a doctor and support .me in every decision I made. For every effort that he do to us

ACKNOWLEDGEMENTS

By the name of God, it is by his grace that the current review has come to exist.

I would like to thank professor **Dr. Raghad AIhashimi**, Dean of College of Dentistry for his great facilitation all the way through the study.

I would like to express my sincere gratitude, grateful and truthful thanks to my academic supervisor **Yassir Rudha Abdul Hussain ALLabban** for the continuous support throughout my project, for his patience, motivation, enthusiasm, immense knowledge. His guidance helped me in all the time of study and the writing of this review. I could not have imagined having a better advisor and mentor for my project.

Finally, I offer my regards and blessing to **my family** for their support and encouragement.

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List of abbreviations

OSA	Obstructive sleap apnea
UA	Upper airway
LA	Lower airway
CBCT	Cone-beam computed tomography
NP	Nasopharynx
OP	Oropharynx
VP	Velopharynx
LP	Laryngopharynx
ADHD	Attention deficit hyperactivity disorder
MRI	Magnetic resonance imaging
VPD	Velopharyngeal dysfunction
AR	Acoustic rhinometry
CPAP	Continous positive airway pressure
AP	Antero-posterior
RME	Rapid maxillary expansion
SARPE	Surgically assisted rapid palatal expansion
SARME	Surgically assisted rapid maxillary expansion
FMA	Frankfort mandibular angle
DO	Distraction osteogenesis
PSG	Polysomnography

RERA	Respiratory effort-related arousals
AHI	Apnea –hypoapnea index
REM	Rapid eye movement
NREM	Non rapid eye movement
RDI	Respiratory disturbance index
SDB	Sleep disorder breathing
ODI	Oxygen desaturation index
UARS	Upper airway resistance syndrome
CSAS	Central sleep apnea syndrome
CSA	Central sleep apnea
CCHS	Congenital central hypoventilation syndrome
OHS	Obesity – hypoventilation syndrome
ENT	Ears, nose and throat specialist

Introduction

Air is essential for human life. The path that air takes into the body and through to the lungs is called the *airway.* Since much of the upper airway (UA) is part of the craniofacial complex, the orthodontist can observe the airway and modulate it in case of potential obstructions.

This places the orthodontist in a strategic position to intervene when airway complications exist or may develop. Since airway obstructions can have far-reaching effects, the importance of airway assessment has been part of orthodontic literature for over a century. Now, more than ever, with the emergence of state of the art technologies and treatment options, the orthodontist has a responsibility and obligation to recognize respiratory problem.

Aims of Study

Focusing the light for the serious subject in last decades releavent to orthodontic treatment, namely obstractive sleep apnea , upper airway resistance syndrome, central sleep apnea syndrome and sleep hypoventilation syndrome.

Chapter One

Review of Literature

1.1 Airway Complication

1.1.1 lack of function (nasal breathing) creats a lack of area of development .

According to Moss' functional matrix theory **(Moss., 1962)** nasal breathing allows the proper growth and development of the craniofacial complex interacting with other functions such as mastication and swallowing ,So every thing in growth respond to function **(Prates., 1997)**.

The typical features that are considered characteristic of persons who have difficulty breathing through their nose, is exemplified by the long-face syndrome **(Fig.3 A) (Schendel., 1976) .** The pediatrician often refers to this as "adenoidal facies." The prototype of this condition is considered to include an increase in lower facial height, lip apart posture, narrow alar base, and "mouthbreathing".

Obstructive cases are related to **1.**hypertrophy of the adenoids and/or tonsils, All immunologically healthy children have adenoids from birth, which reach peak growth between four and 5 years of age and then undergo a process of atrophy, which is complete at around 10 years of age**(Bluestone., 1992).**
2. deviated nasal septum **3.**nasal polyp **4.**sinusitis and nasopharyngitis
5. rhinitis,which is inflammatory process of the nasal mucosa sufficient to provoke unilateral or bilateral nasal obstruction with intermittent or persistent obstructin resulting from hypertrophy of the inferior, middle or superior nasal conchae**(Nieto., 2015)**.

The clinician might expect to find a narrow maxillary arch with a high palatal vault and a posterior crossbite with a Class II dental malocclusion **(Fig.3 B And C)**.

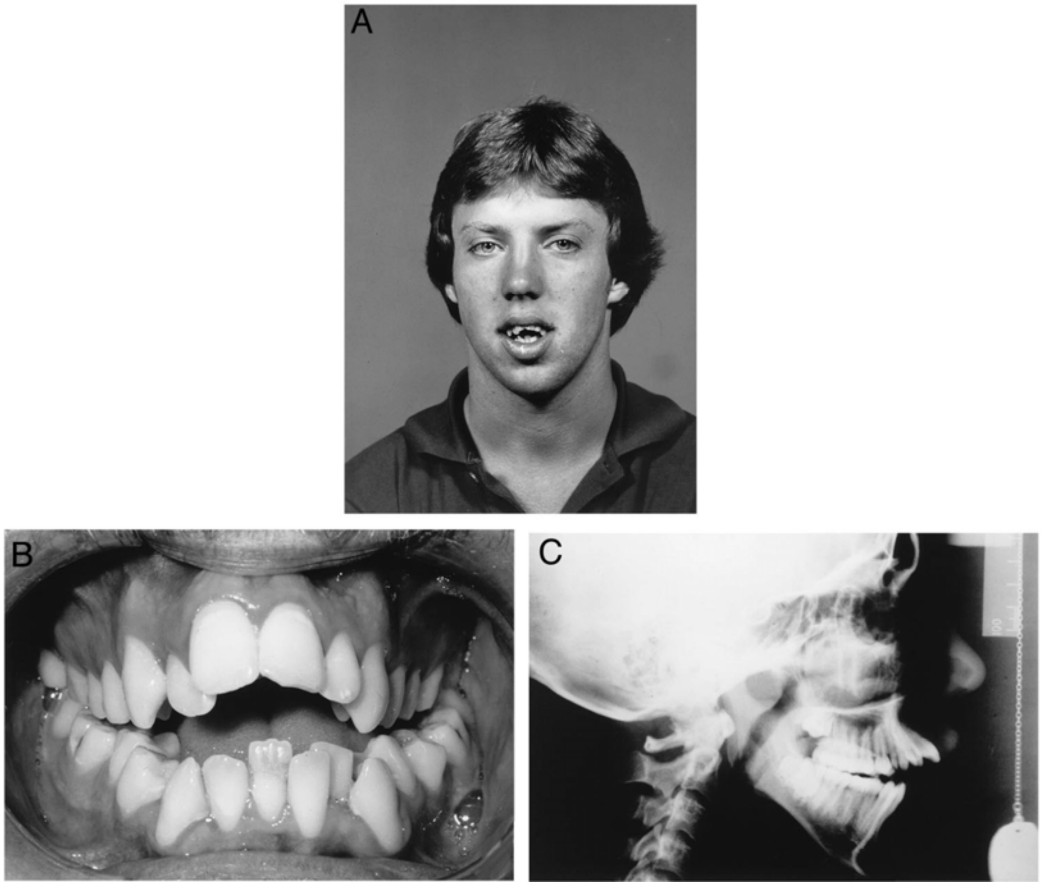

Fig.3 A, Sixteen-year-old boy with an increase in lower face height, lip apart posture, and narrow alar base. **B**, Anterior view in occlusion. Note anterior open bite, bilateral posterior crossbite associated with transverse maxillary deficiency, and crowding of incisors. **C**, Lateral cephalogram confirms increase in lower facial height, vertical maxillary excess, and skeletal open bite **(Katherine et al., 1998)** .

1.1.2 Higher level of plaque , caries , gingival inflammation

As a result of lip incompetence, salivary flow to the area is decreased, resulting in reduced effects of salivary cleaning mechanisms. The incidence of caries is increased, and maxillary anterior teeth are most affected.

This repeatedly alternates from wet to dry gingiva results in a histologically incomplete keratinization of the gingiva. Clinically, the gingival has a red color, rolled gingival margins, and bulbous papilla**(Lite *et al.*, 1955).**

Inflammation may occur alone or with hyperplasia. Mouth breathing, increased lip separation, and decreased upper lip coverage at rest have all been associated with higher levels of plaque and gingival inflammation**(Wagaiyu *et al*., 1991).**

As a result of long-term plaque accumulation and poor oral hygiene, a mouth breather's gingivitis can progress to pocket formation and bone loss.

1.1.3 hypoxemia, hypercarbia, and hypoventilation after only 24 hours of nasal obstruction

Breathing through the nose increases blood circulation ,oxygen absorption in the lungs from 10% to 25% and carbon dioxide levels, slows the breathing rate (Normal respiration rate ranges from 12 to 18 breaths per minute.) But those who breathe through their mouth possess a respiration rate that is much higher. Asthmatic and people with pre-existing medical conditions have respiration rate above 20. Low CO_2 levels in the body is often linked to mouth breathing, which is associated with faster breathing. This in turn causes overbreathing or hyperventilation **(Douglas., 1909)**.

1.1.4 Adults who habitually breathe through the mouth, attributable to nasal obstruction, are more likely to have sleep disorders and attention-deficit / hyperactivity disorder (ADHD).

Studies have shown that altered sleep patterns and sleep apnea are common in children with persistent mouth breathing. Such children also suffer from problems such as difficulty in sustaining attention in school, easy fatigability, lethargy, and behavioral problems. These symptoms are similar to the symptoms in attention deficit hyperactivity disorder (ADHD) leading to misdiagnosis of ADHD in many children with sleep disorders in mouth breathers**(Huang *et al*., 2007) (Sano *et al*., 2013).**

Literature also shows that children with breathing problems like snoring, mouth breathing, or apnea are 40–100 times more likely to develop behavioral problems resembling ADHD**(Schredl *et al*., 2007)**.

As per the data of the National Sleep Foundation, ADHD may be associated with a variety of sleep problems.

Parents of 25–50% ADHD children complain of sleep difficulties in these children. Inadequate sleep can affect thinking, functioning, and behavior. Sleeping problems have also been shown to induce ADHD symptoms (hyperactivity, impulsivity, and inattention).

1.1.5 progression of Heart failure , Atherosclerosis , Coronary artery disease , Ischemic cardiomyopathy.

Exaggerated negative intrathoracic pressure (Intrapleural pressure which is pressure between two layers of pleura and always negative in normal people) during obstructive apneas further increases left ventricular after load, reduces cardiac output, and may promote the progression of heart failure **(Christie and Meakins., 1934).**

Intermittent hypoxia and postapneic reoxygenation cause vascular endothelial damage, which can progress to atherosclerosis and, consequently, to coronary artery disease and ischemic cardiomyopathy.

1.2 AIRWAY MEASUREMENTS AND IMAGING

A number of techniques have been used to study the airway, including nasal pharyngoscopy, cephalometric radiographs, fluoroscopy, conventional and electron-beam CT, acoustic reflection, and MRI**(Welch *et al*., 2002)**.

1.2.1 Magnetic resonance imaging (MRI)

MRI provides an intrinsically scaled, three-dimensional image of all tissues composing the structure of the upper airway. Moreover, MRI provides superior resolution for soft tissues as compared with other techniques commonly used to assess the upper airway structures both in normal children and in children evaluated for obstructive sleep apnea (OSA) **(Fujioka *et al*., 1997)**

It is not as useful in orthodontics because use fixed metal orthodontic appliances can produce artifacts and obscure the area of the MRI**(Welch *et al*., 2002)**.

1.2.2 Cephalograms

Cephalograms which provides a 2D radiographic view of the patient profile. have been found useful in identifying airway obstruction, adenoid hypertrophy, and very constricted airways**(Lanni Filho *et al*., 2001)**.

However, as a two-dimensional representation of three-dimensional (3D) structures (a3D structure in 2D) , lateral cephalographs offer limited information about the airways **(Guijarro-Martínez and Swennen., 2011)**

Information regarding axial cross-sectional areas and overall volumes can only be determined by 3D imaging modalities **(Aboudara *et al*., 2009)**

1.2.3 Nasoendoscopy

An analysis of velopharyngeal performance may require the use of procedures such as nasopharyngoscopy and videofluoroscopy.

More specifically, during nasoendoscopic assessment one can observe velopharyngeal patterns of closure (or best attempt to closure) having the possibility of determining the factors that contribute to velopharyngeal dysfunction (VPD) (Mean soft palate can not touch pharyngeal wall during speech so air is able to escape through the nose which make it harder to understand the speech) Because many procedures are available to correct VPD, an adequate treatment decision may require the identification of the pattern of velopharyngeal functioning for speech with specific ratings of movement of the velum as well as the pharyngeal walls **(Seagle *et al*., 2002)**.

While the optimization of information obtained during the decision making process is possible when nasoendoscopy and videofluoroscopy are used as complementary procedures **(Nagarajan *et al*., 2009) (Williams *et al*., 2004)**

Nasoendoscopic assessment does not involve radiation allowing for an extended time of examination during which one can attempt to modify velopharyngeal function.

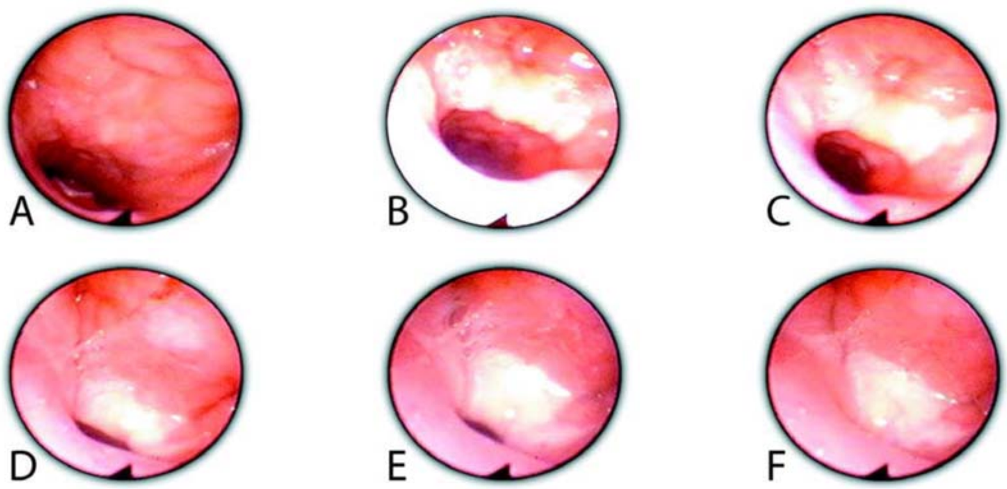

Fig.4 Nasoendoscopic images of the velopharynx for one participant before and during diagnostic therapy. **A**: At rest; **B**: Production of /pa/ before diagnostic therapy; **C**: Production of /pa/ at the beginning of diagnostic therapy; **D** & **E**: Production of /pa/ showing reduction in the size of the velopharyngeal gap as the diagnostic therapy progressed; **F**: Production of /pa/ showing elimination of velopharyngeal gap during diagnostic ther**(Pegoraro-Krook *et al*., 2008).**

1.2.4 Cone-Beam Computed Tomography (CBCT)

CBCT is very popular in orthodontics and has brought 3D radiography to clinical orthodontics.

The principle behind this technique is a cone-shaped x-ray bundle, with the x-ray source and detector (image intensifier or flat-panel detector) rotating around a point (or field) of interest of the patient.

The conical shape of the beam distinguishes this technique from helical CT, which uses a fan-shaped beam.

During a CBCT scan, the scanner (x-ray source and a rigidly coupled sensor) rotates, usually 360 degrees, around the head to obtain multiple images (ranging from approximately 150 to 599 unique radiographic views).

These 2D images received by the detector are then compiled by the acquiring software into volumetric data, creating a 3D image (primary reconstruction).

The latest generation CBCT scanners are able to scan a patient with 180-degree rotation and with pulse technology, which uses radiation only when capturing the 2D images, resulting in approximately 2 seconds of total radiation time **(Ludlow and Walker., 2013)**.

In addition, CBCT may now result in less radiation exposure to the patient than the usual combination of a panoramic radiograph and a lateral cephalogram.

The airway can be accurately assessed through segmentation .
In medical imaging, segmentation is defined as the construction of 3D virtual surface models to match the volumetric data**(Grauer *et al*., 2009).**

UA segmentation can be performed either manually or semiautomatically. In the manual approach, the user identifies the airway in each slice through the length of the airway **(Fig.5)**.

The software then combines all slices to form a 3D volume. This method is time-consuming and almost impractical for clinical application. In contrast, semiautomatic segmentation of the airway is significantly faster**.(El and Palomo., 2010)**

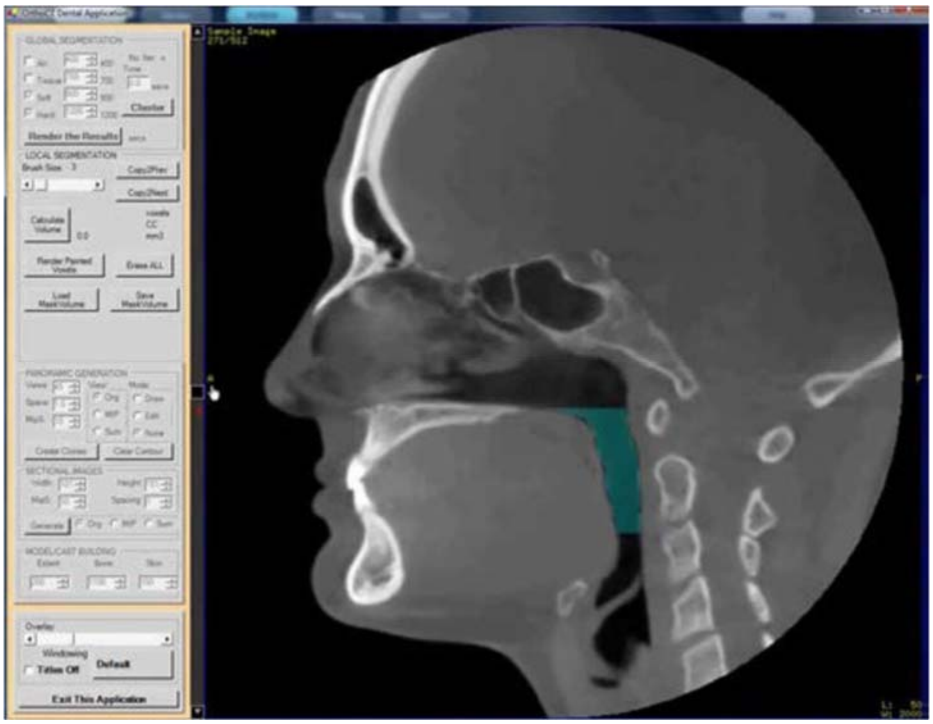

Fig. 5 Manual segmentation of the airway. When performing a manual segmentation of the airway, the user identifies the airway in each slice through the length of the airway. This is a labor-intensive procedure that gives the operator total segmentation control. **(Graber., 2017)**

1.2.5 Acoustic Rhinometry

It is objective method for examining the nasal cavity **(Fig.6)**
This technique is based on the principle that a sound pulse propagating in the nasal cavity is reflected by local changes in acoustic impedance.

Acoustic rhinometry is a quick, painless, noninvasive method that can be used to estimate the dimensions of nasal obstructions, evaluate nasal cavity geometry(like paranasal sinus), monitor nasal disorders, and assess surgical results and response to medical treatment. However, lack of standardization is one of the main problems with this method **(Hilberg *et al*., 1989)**

Numminen concluded that AR is clinically useful and shows very good reliability in the anterior and middle parts of the nasal cavities but decreasing accuracy in the posterior part.

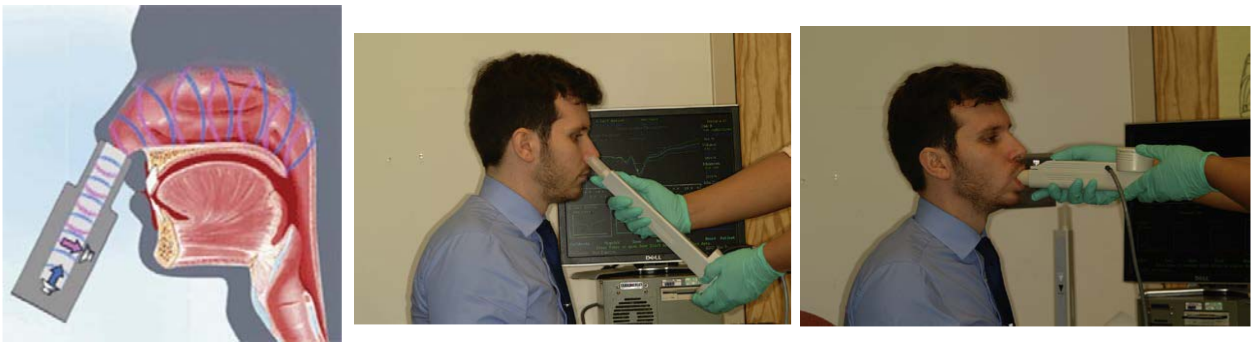

Fig.6 A, Drawing illustrates how rhinometry measures the airway through sound waves.Capturing rhinometry (B), pharyngometry (C), and data collected through pharyngometry. **(Graber., 2017)**

1.2.6 Pharyngometry

This technique has been previously applied to study pharyngeal area , The volumes of the oral cavity (between the incisors and oropharyngeal junction) and the pharynx (between the oropharyngeal junction and glottis) were calculated with the mean pharyngeal area**(Bokov *et al*., 2019).**

Pharyngometry provides a noninvasive assessment of the dimensions, structure, and physiologic behavior of the UA from the oral cavity to the hypopharnyx while the patient breathes.

Computer processing of the incident and reflected sound waves from the airways provide an area distance curve that represents the lumen from which minimal cross-sectional area and volume can be derived.

This dynamic test measures the dimensions of the airway through the oral cavity and 25 cm down the pharynx.

The authors concluded that pharyngometry not a standardized test, acoustic pharyngometry was shown to be a useful method to assess OSA and in postoperative monitoring of UA surgery in patients with sleep disorders. When attempting to maintain good reliability and obtain accurate results, posture may play an important role in determining the pharyngeal area. Flexion of the neck and back, as well as raising the shoulders (which occurs near residual volume), may compress the pharynx and decrease its cross-sectional area **(Brown *et al*.,1986).**

Pharyngometry is often marketed as a screening method to assess quickly a patient for potential sites of sleep-related UA obstruction and to better determine whether an OA or continuous positive airway pressure (CPAP) device may be appropriate for the patient.

1.3 Influence Of Orthodontic Treatment On The Airway

1.3.1 Treatment Including Extractions

It is well documented in the literature that after four premolar extractions using maximum anchorage mechanics, a change in the soft tissue profile, retraction and uprighting of upper and lower incisors, and a slight change in the mandibular plane may be observed**(Bravo., 1994)(Bishara., 1997).**

On the other hand, minimum anchorage mechanics may sometimes be desired for patients having good facial balance and moderate crowding, as well as when a counterclockwise rotation of the mandible is anticipated.

Closure of extraction sites with mesial movement carries the molar to a narrower part of the arch, which could potentially have an effect on the tongue position **(Germec-Cakan *et al*., 2011)**.

Tongue position is considered to be an important factor for the UA since the root and posterior part of the tongue form the anterior wall of the oropharynx. Existing evidence suggests that extraction treatment with maximum anchorage mechanics may cause the tongue's length and height to decrease slightly and move to a more retracted position against the soft palate **(Germec-Cakan *et al*., 2011)(Chen *et al*., 2012)**.

This movement results in an adaptation and may lead to the narrowing of the UA.

Valiathan and colleagues assessed 40 subjects (20 with extractions and 20 age- and gender-matched controls without extractions) and reached a conclusion that extractions do not affect the oropharyngeal dimensions**(Valiathan *et al*., 2010).**

Furthermore, no adverse effects of extraction treatment over the nasopharynx area have been reported to date.

Explanation for UA reduction after incisor retraction is the movement of the hyoid bone in a posterior and inferior direction**(Wang *et al*., 2012).**

Wang and colleagues reported that this change in hyoid bone position was an adaptation that prevents an encroachment of the tongue into the pharyngeal airway.

On the other hand, mesial movement of the molars in to extraction spaces seems to enlarge the space behind the tongue, which is considered to play a vigorous role in improving UA dimensions**(Wang *et al*., 2012).**

It has been reported that hyperdivergent patients with an obtuse mandibular plane angle have a narrower AP pharyngeal dimension, compared with normodivergent patients**(Kim *et al*., 2010).**

Therefore obtaining a counterclockwise rotation and a forward positioning of the mandible in such situations may contribute to enhanced dimensional changes in the UA.

1.3.2 Rapid Maxillary Expansion

Rapid maxillary expansion (RME) is commonly used to correct maxillary constriction **(Haas., 1961)**.

Because of the nature of the procedure, an increase in the nasal cavity width and posterior nasal airway is anticipated, not only attributable to the opening of the median palatal suture but also to an increase in the sagittal and vertical dimensions**(Baratieri *et al*., 2011).**

As a result, an improvement in nasal respiration is expected, along with expansion in patients with a transverse arch discrepancy**(Habeeb *et al*., 2013)**.

Surgically assisted rapid palatal expansion (SARPE)(is an effective and stable method of addressing severe maxillary transverse discrepancy in patients over the age of 15 years of age **(Anttila *et al*., 2004)**.

On the other hand, is a frequently used surgical modality of RME preferred in skeletally mature individuals to overcome the resistance of the closed sutures**(Bell and Epker., 1976)**.

The effects of RME are not limited to the upper jaw because the maxilla is connected with many other bones**(Ceylan *et al*., 1996)**.

RME separates the external walls of the nasal cavity laterally and causes lowering of the palatal vault and straightening of the nasal septum**(Haas., 1961)**

This remodeling decreases nasal resistance, increases internasal capacity, and improves breathing**(Linder-Aronson and Aschan., 1963)**.

Surgical expansion increased the minimal nasal cross-sectional area approximately 55% so increase nasal volume .

Nasal volume changes in SARME group were similar to those in RME group. Therefore, it was suggested that SARME in adults was as effective as RME in adolescents.

Studies have documented nasal resistance reduction and intranasal capacity increase with both RME and SARPE treatments**(Babacan *et al*.,2006).**

After RME, the increase in intermolar width is a fact, especially in the maxillary arch, which may cause the tongue to reposition more anteriorly in the oral cavity**(Schmidt-Nowara *et al*., 1995).**

Additionally, secondary to RME treatment, mandibular position also changes in various directions in patients with different malocclusions**(Farronato *et al*., 2011).**

1.3.3 Functional Orthopedic Appliances

Mandibular corpus length and oropharyngeal airway volume, along with minimum axial area, have shown a positive correlation**(Trenouth and Timms., 1999).**

Thus thinking that functional appliances that advance the mandible could have a positive impact over the UA is logical, and an increase in the oropharyngeal airway dimensions has been previously reported**(Ozbek *et al*., 1998).**

When the mandible is protruded, a different posture of the tongue caused by increased genioglossus muscle activity and/or other soft tissue activity may play an important role over airway dimensions**(Battagel *et al*., 1999).**

A study by Hanggi and associates, using activator-headgear therapy in patients with a mean age of 10.2 years, showed improved distance behind the tongue (velopharynx) by 2.5 mm on average, resulting in an increase of the oropharyngeal dimensions**(Hänggi *et al*., 2008)**.

Iwasaki and colleagues found that a frequently used fixed functional appliance, the Herbst appliance (American Orthodontics, Sheboygan, WI), enlarges the oropharyngeal and laryngopharyngeal airways of Class II subjects at the prepubertal growth spurt stage, compared with an age-, sex-, and Frankfort mandibular angle (FMA)-matched skeletal Class I subjects**(Iwasaki *et al*., 2014).**

On the other hand, when fixed functional appliances are used in the later stages of growth, when most dental changes take place, no significant posterior airway changes are usually seen after treatment is completed**(Ozdemir *et al*., 2014)**.

Other extensively used orthopedic appliances are headgears, to inhibit the forward maxillary growth, and the face mask for maxillary protraction. Kirjavainen and Kirjavainen found that cervical headgear treatment increased the velopharyngeal airway space but did not significantly affect the rest of the oropharynx or hypopharynx**(Kirjavainen and Kirjavainen., 2007)**.

Although headgear treatment is intended to restrict the forward growth of the maxilla, which may suggest a negative influence over the airway, they speculated that this restriction was only limited to the maxillary alveolar process. Headgear is extensively used by patients during sleep.

1.3.4 Orthognathic Surgery

The most common surgical procedures can be roughly categorized as concerning the mandibular or maxillary region only and bimaxillary surgical procedures.

A consensus in the literature suggests that when mandibular setback osteotomy is performed, the hyoid bone tends to move to a more posterior and inferior position, and the tongue is carried to a more posterior position, regardless of whether using bilateral intraoral vertical ramus osteotomy or sagittal split ramus osteotomy**(Enacar *et al*., 2007).**

As a result, narrowing in the width and depth of the hypopharyngeal and oropharyngeal areas has been reported.

On the contrary, mandibular advancement surgery results in an increase in the dimensions of the oropharyngeal airway**(Eggensperger *et al*., 2005).**

Maxillary advancement, on the other hand, creates a significant increase in the nasopharyngeal and oropharyngeal airway dimensions. It has also been reported that hypopharyngeal airway may as well present an enlargement after maxillary advancement **(Greco *et al*., 2005).**

Therefore performing bimaxillary orthognathic surgery rather than only mandibular setback surgery would be advisable, even if the patient exhibits mandibular prognathia.

Probably the highest gain in the UA is obtained with maxillomandibular advancement surgery, which is a frequently used surgical modality in the treatment of patients with OSA **(Mattos *et al*., 2011)**.

Additionally, when maxillomandibular advancement surgery is performed in conjunction with genial tubercle advancement, which pulls the geniohyoid and genioglossus muscles forward, the gain in the UA is even better**(Prinsell., 1999)**.

Distraction osteogenesis (DO) has become an accepted method of treatment for patients requiring reconstruction of a hypoplastic mandible and a severely retruded maxilla to increase airway dimensions**(Rachmiel *et al*., 2005).**

Similarly, mandibular DO has been proposed as a useful method to resolve oropharynx airway obstruction**(Morovic and Monasterio., 2000).**

This effect is primarily due to the displacement of the hyoid bone away from the posterior pharyngeal wall**(Perlyn *et al*., 2002).**

Furthermore, the small size of the mandible and its retruded position causes a corresponding retrodisplacement of the tongue, which also contributes to a reduction in the airway. Mandibular DO also creates a change in the position of the tongue and is believed to aid in increasing the airway **(Fig. 7) (Cohen *et al*., 1998).**

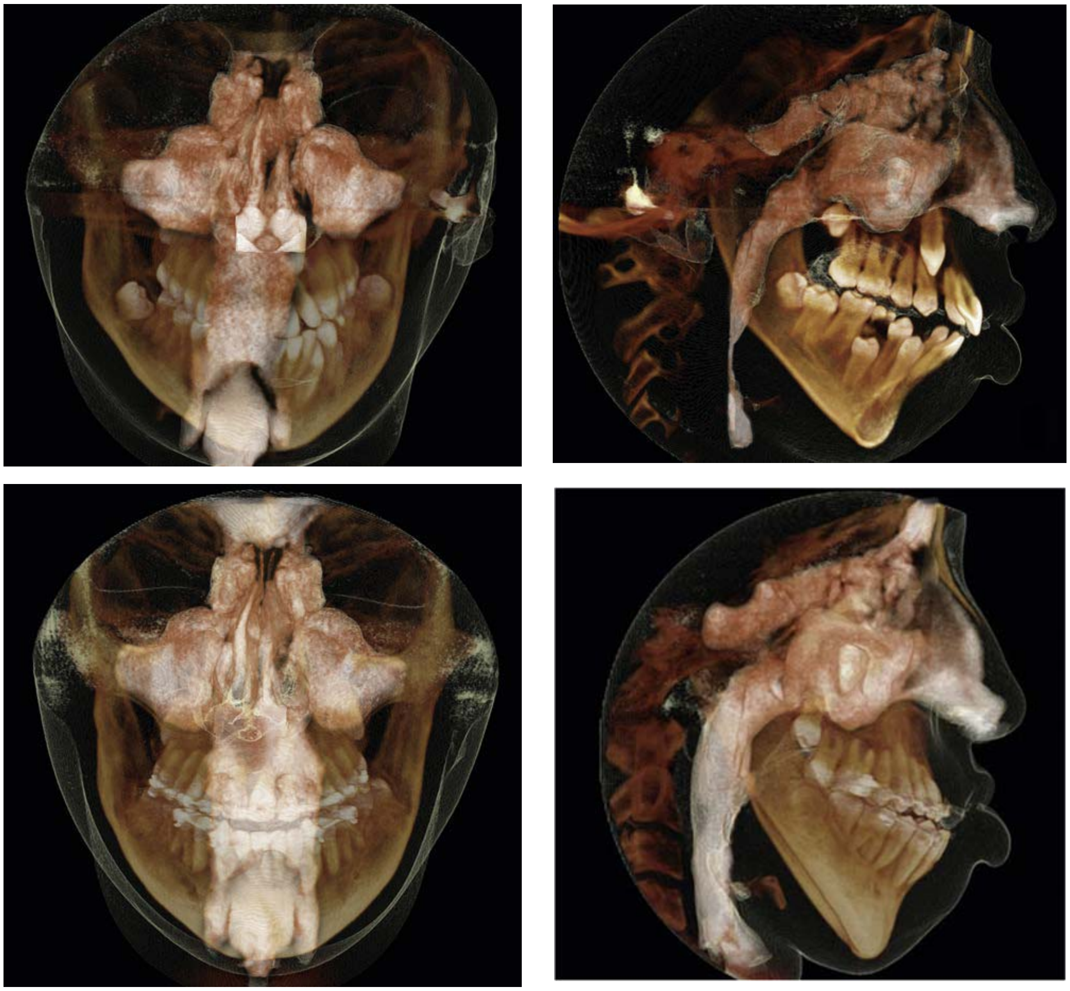

Fig. 7 Figure showing the airway changes in a patient treated with mandibular distractor, A and B show frontal and lateral pre-treatment views, while C and D show the equivalent post mandibular distractor views **(Graber., 2017)**.

1.4 Sleep-Disorder Breathing : Definitions and Testing Reports

Breathing abnormalities detected during sleep are classified as apnea, hypopnea, respiratory effort–related arousals, and hypoventilation.

1.4.1 Apnea

Is the cessation, or near cessation, of airflow. It exists when airflow is less than 20% of baseline for at least 10 seconds in adults**(Berry *et al.*, 2007).**

Apnea is most commonly detected using airflow sensors placed at the nose and mouth of the sleeping patient. Inspiratory airflow is typically used to identify an apnea, although both inspiratory and expiratory airflows are usually abnormal. Some laboratories use surrogate measures instead, such as inspiratory chest wall expansion. Three types of apneas may be observed during sleep:

- **OSA** occurs when airflow is absent or nearly absent but ventilator effort persists. It is caused by complete, or nearly complete, UA obstruction.
- **Central apnea** occurs when both airflow and ventilator effort are absent.
- **Mixed apnea** is mix of intervals during which no respiratory efforts occur (i.e., central apnea pattern) and intervals during which obstructed respiratory efforts occur.

1.4.2 Hypopnea

Which is an abnormal reduction of airflow to a degree that is insufficient to meet the criteria for an apnea. As further classified, obstructive hypopneas are due to partial UA obstruction, which can be heard as snoring. Central hypopneas are due to reduced inspiratory effort.

Although the criteria for hypopnea vary among sleep laboratories like PSG can be performed as an in-laboratory full-night or splitnight test that includes the analysis of the following tests: electroencephalogram, electrooculogram, chin electromyogram, airflow analysis, oxygen saturation, respiratory effort, and electrocardiogram, sometimes replaced by heart rate. Body position and excessive movements are also observed during this test **(Epstein e*t al*., 2009).**

A common definition is ≥30% reduction of breathing movements or airflow for at least 10 seconds, with ≥3% or 4% oxyhemoglobin desaturation. Similarly to apnea, hypopnea is detected using airflow sensors or surrogate measures, such as chest wall expansion.

1.4.3 respiratory effort– related arousals (RERAs)

Which are episodes during which breathing and oxygenation are maintained at the expense of a great increase in respiratory efforts, results from increased UA resistance. which is often characterized by a resuscitative snore or an abrupt change in respiratory measures with arousal and a change in breathing sounds.

1.4.4 Sleep hypoventilation

Is expressed by a reduction in only the oxygen level or an increase in the carbon dioxide level without measurable changes in breathing patterns evident in the airflow monitor.

1.5 Index to assess severty of sleap apnea

1.5.1 Apnea-Hypopnea Index (AHI)

Is the total number of apneas and hypopneas per hour of sleep. The AHI is most commonly calculated per hour of total sleep and is the current defining measure of disease and disease risk**(Redline *et al*., 2010).**

However, an AHI is occasionally calculated per hour of non- REM sleep, per hour of REM sleep, or per hour of sleep in a certain position to provide insight into the sleep-stage dependency or sleep-position dependency.

Table 1: Use AHI to assess severty of OSA (Graber., 2017)

AHI	**Severty Of OSA**
4 or less	Within normal limits
15-5	Mild
15-29	Moderate
30 and higher	Severe

1.5.2Respiratory Disturbance Index (RDI)—The RDI is the total number of events (apneas, hypopneas, and RERAs) per hour of sleep. The RDI is generally larger than the AHI, because the RDI considers the frequency of RERAs, whereas the AHI does not**(Berry *et al*., 2007).**

Table 2: Use RDI to assess severty of OSA (Graber., 2017)

RDI	**Severty Of OSA**
5-15	Mild
15-30	Moderate
30 or more	Severe

1.5.3 Reporting oxygen saturation.

Oxygen desaturation is a consequence of SDB. The oxygen desaturation index (ODI) is the number of times that the oxygen saturation falls by more than 3% to 4% per hour of sleep. The percent of sleep time during which oxygen saturation is <90% quantifies the exposure to hypoxemia. This measure and mean oxygen saturation are associated with a risk for cardiovascular disorders and glucose intolerance**(Punjabi and Polotsky., 2005)**.

Minimum levels (i.e., troughs) of oxygen saturation are important because severe hypoxemia is considered a risk for cardiac arrhythmias**(Monahan *et al.*, 2009).**

1.5 Classifications of Sleep-Disordered Breathing

1.5.1 Obstructive Sleep Apnea

. OSA is defined as either **(Strohl and Redline., 1996)**:

• More than 15 apneas, hypopneas, or RERAs per hour of sleep (i.e., an AHI or RDI >15 events per hour) in an asymptomatic patient, OR

• More than 5 apneas, hypopneas, or RERAs per hour of sleep (i.e., an AHI or RDI >5 events per hour) in a patient with symptoms (e.g., sleepiness, fatigue, inattention) or signs of disturbed sleep (e.g., snoring, restless sleep, respiratory pauses).

OSA syndrome applies only to the latter definition. In both situations, more than 75% of the apneas or hypopneas must have an obstructive pattern

1.5.2 Upper Airway Resistance Syndrome

Individuals previously diagnosed with upper airway resistance syndrome (UARS) are now classified as having OSA by the most recent *International Classification of Sleep Disorders—Third Edition* (ICSD-3)**(Rosenberg and Van Hout., 2013).**

UARS refers to RERAs accompanied by symptoms or signs of disturbed sleep.

1.5.3 Central Sleep Apnea Syndrome

Central sleep apnea syndrome (CSAS) exists when symptoms or signs of disturbed sleep are accompanied by more than five central apneas plus hypopneas per hour of sleep and normocarbia during wakefulness**(Rapoport., 2016).**

A special case of recurrent central apneas is called Cheyne-Stokes respiration and refers to a cyclic pattern of central apneas and crescendo-decrescendo tidal volumes. Cheyne- Stokes respiration is considered a type of CSA and is commonly associated with heart failure or stroke. UA obstruction does not play a major role in this syndrome.

1.5.4 Sleep Hypoventilation Syndromes

Patients with one of the hypoventilation syndromes generally have mild hypercarbia when awake, which worsens during sleep. The two hypoventilation syndromes are congenital central hypoventilation syndrome (CCHS) and obesity //hypoventilation syndrome (OHS).

CHAPTER TWO : DISCUSSION

Sleep plays a vital role in good health and well-being throughout life. Getting enough quality sleep can help protect mental health, physical health, quality of life, and safety. Inadequate sleep contributes to heart disease, diabetes, depression, falls, accidents, impaired cognition, and a poor quality of life. In children and teenagers, sleep also supports growth and development **(Young *Et al.*, 2002)**.

OSA, which the orthodontist will most frequently encounter, is considered part of a group of disorders called sleep disordered breathing (SDB). This class of disorders refers to abnormal respiratory patterning during sleep; but, ironically its presence or a suspicion of disease is made when the patient is awake. A finding of a narrow airway or a report of heavy snoring results only in a pre-test probability for any one of a number of respiratory pattern abnormalities, all which produce decreases in oxygen and increases in carbon dioxide levels, and arousals during sleep **(Young *Et al.*, 2002)**.

Sleepiness by itself is not specific for SDB. OSA is estimated to affect approximately 8% of men and 2% of women, averaging 5% of the general population, with many affected individuals going undiagnosed, considering themselves as healthy individuals**(Young *Et al.*, 2002)**.

The orthodontist who treats many patients a day probably encounters several people daily with OSA **(Ngiam *et al.*, 2013).**

Although the role of the orthodontist is not to diagnose SDB, an opportunity to screen for SDB exists. Proper diagnosis can only be done through polysomnography (PSG) or home testing with portable monitors, with PSG being the gold standard **(Ngiam *et al.*, 2013).**

It is important for the orthodontist to recognize the signs and symptoms of SDB and refer the patient to a sleep medicine physician for proper diagnosis. An otorhinolaryngologist (also known as ENT physician), may also be consulted in suspected cases of chronic nasal obstruction or adenotonsillar hypertrophy **(Ngiam *et al*., 2013).**

The mean minimum cross-sectional area across multiple segments of the UA has been measured using several techniques , wide range of sizes for minimum cross – sectional area reflects the differences attributable to individual variability but also to differing locations of measurement, positional change (sitting or supine), and differences imposed by the choice of imaging modality (e.g., mouth open is required for acoustic reflection).

Cheyne-Stokes respiration has received considerable attention in the last decade due to its association with heart failure and stroke, two major causes of mortality, and morbidity in developed countries. Unlike obstructive sleep apnea (OSA), which can be the cause of heart failure, Cheyne-Stokes respiration is believed to be a result of heart failure.

Chapter three: Conclusion

Studies show that certain orthodontic treatments may impact the UA, but there are limitations on this impact. Therefore some final recommendations in light of current literature can be as follows:

• Extraction treatment does not seem to affect the airway's size, but caution may be taken in patients who have respiratory problems and avoiding maximum anchorage approaches

• RME may be able to help solve the nasal resistance to airflow if the problem originates from the anterior nasal cavity.

• Functional appliances are most useful in patients with a horizontal growth pattern of the mandible. So IF , using fixed or removable appliances in a timely fashion may increase the dimensions of the airway. On the contrary, vertical-growing patients may not benefit from such a treatment since it is not the sagittal correction but rather a counterclockwise rotation that may increase the airway space.

• When planning surgical treatments, consideration should be given to avoiding large amounts of mandibular setback even if the patient's diagnostic records indicate mandibular prognathia. Bimaxillary surgeries are probably better choices for such patients.

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