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Airway and Orthodontics

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Abstract

The concept of health is greatly recognized association of physical, mental & social well-being along with the improvement in quality of life of an individual. Orthodontics is now recognized a branch in dentistry that is not only associated with correction of malocclusion but also with enhancement of dento-facial structures. There has been increase in the interest in sleep breathing disorders which includes central sleep apnea, obstructive sleep apnea (OSA), and sleep related hypoventilation/ hypoxia. Upper airway obstruction has a significant impact on growth & development of craniofacial structures which requires early detection & treatment planning. Upper airway assessment includes clinical examination, otorhinolaryngology tests & supplemental tests. Volumetric reconstruction obtained by CBCT helps in assessing the airway in 3-dimensional view in different plane in different skeletal & growth patterns. This article reviews the effect of craniofacial abnormalities and the effect of different orthodontic and orthognathic procedures on the airway dimensions. Reduced airway volume results in compromised quality of life of individual.Knowledge about airway in orthodontics gives us an opportunity to not only improve appearance, but also to improve our patients’ health & everyday lives. Hence it is important for an orthodontics to have a thorough knowledge of airway anatomy & physiology and an understanding about how the airway gets affected by the treatment we provide.

Keywords: Airway, Obstructive Sleep Apnoea, Orthodontics.

Introduction

Main objective of orthodontics treatment is to improve the dentofacial aesthetics which leads to enhancement of improvement in quality of life[1]. With the emergence of sleep medicine, it has come to knowledge that the jaw size and its spatial orientation has emerged as the key determinant of optimizing upper airway physiology[2]. Upper airway obstruction tends to alter breathing, which can have a significant impact on the normal development of craniofacial structures, causing deficiencies in transverse maxillary growth, as well as backward rotation of the mandible. Early detection of this anomaly has shown that there is an almost complete normalization of dentofacial morphology of obstructive sleep apnea-hypopnea syndrome[3].The sagittal relationships of maxilla and mandible relative to the cranium have shown to influence the upper airway morphology. Many craniofacial abnormalities such as cleft lip & palate, Obstructive sleep apnea, long face syndrome, mouth breathing are affected by narrowing of upper & lower airway. Midface retrusion in cleft lip and palate patients often lead to functional, aesthetic, and psychological problems in occlusion, speech, breathing, swallowing as well as the aesthetic concerns are affected in various degrees throughout the growing period. During orthodontic treatment procedures such has extraction, expansion, use of functional appliances, orthognathic surgeries & distraction osteogensis have shown to influence the airway dimensions. Hence, it is important for an orthodontist to have a thorough knowledge of anatomy & physiology of airway. Malocclusions & dentofacial deformities, their treatment options also can influence the airway dimensions, enabling us to identify the main aetiology and formulate the suitable treatment plan for our patients.

Anatomy of airway

The airway can be divided into upper airway, which includes the nasal cavity, the oral cavity, the pharynx, and the larynx, and the lower airway, which consists of tracheobronchial tree[4]. [Fig.1] The nose is divided into external nose & the nasal cavity. The external nose is formed by a pyramidal structure made of skeletal framework which is partly bony and partly cartilagenous[5]. The paranasal sinuses make the skull lighter; adding resonance to voice. The nose is the main portal of air exchange between the inner and the outer environment which creates a favourable conditions of approximately 37.8° and 100% relative humidity of respiratory air which is required for vital functions, and also the local defence and filtering of particulate matter and gases. Oral cavity consists of mouth, palate, teeth, and tongue. Oral cavity is more preferred for airway instrumentation due to the narrow nasal passages and the high possibility of bleeding after trauma. A smaller size mandible provides insufficient space for tongue thus reducing the size of airway. The pharynx is a tube-like passage that connects the posterior nasal and oral cavities to the larynx and oesophagus. It is divided into nasopharynx, oropharynx, and laryngopharynx. There are 20 or more airway upper muscles surrounding the airway which actively constricting and expanding the upper respiratory tract lumen[6]. The nasopharynx lies behind the nasal cavity and above the soft palate and communicates with the oropharynx through the pharyngeal isthmus, which becomes closed off during the act of swallowing. The oral cavity enters the oropharynx via oropharyngeal isthmus, which is limited by palatoglossal arches, soft palate, and lingual dorsum. The laryngopharynx is the last part of the pharynx extending from the edge of the epiglottis to the lower border of the cricoid at the level of C6. Larynx is a complex structure of cartilage, muscles, and ligaments that serves as the entrance to the trachea and performs various functions, including phonation and airway protection[7].

Assessment of Airway

Upper airway assessment and its interactions with craniofacial growth and development have been of interest to ENT specialists, laryngologists, speech therapists, paediatricians and dentists[8]. Airway assessment can be done by clinical examination by evaluating the facial morphology, skeletal jaw relationships, functional assessment of nostrils, the size and function of the tongue and the anatomy of the soft palate, uvula and tonsils. The methods described to assess the airway include: nasal endoscopy, rhinomanometry, acoustic rhinomanometry, cephalometry, computed tomography (CT), magnetic resonance imaging (MRI) and cone-beam computed tomography (CBCT). Volumetric reconstructions that may be obtained from CBCTs help clinicians make a correct diagnosis and indicate a better treatment plan for some pathologies of the maxillofacial area, especially those related to the airway[9]. Yamashina et al[10] concluded that the airway volume acquired from CBCT is nearly a one-to-one representation of the real volume and the measurements thus obtained of the air space surrounded by soft tissues are accurate. [Fig.2]

Relationship of Different Malocclusion and Airway

Breathing pattern is an important factor that can affect normal growth of the craniofacial structures[11]. The effects of respiratory function on craniofacial growth have been studied for decades & shown that the airway controls the vital functional process like swallowing and phonation and it dynamically contributes to the development of overall facial morphology and the ideal occlusion. An orthodontist deals with various kinds of malocclusions, including severe skeletal Class II and Class III deformities. According to Balter's the aetiology for the Class II malocclusion is the backward positioning of the tongue. Faulty deglutition and mouth breathing in Class II with prognathic maxilla indicates the narrow oropharynx airway with mandibular retrognathism[12]. Kim et al[13] stated that retrognathic patients tended to have a smaller oropharyngeal airway volume compared with patients with a normal anteroposterior skeletal relationship. Whereas, according to study done by Tarkar et al[14] on Indian populations with different sagittal patterns concluded that the dimensions of pharyngeal airway decreased from Class III to Class I to Class II. This increase in the oropharyngeal dimensions is due to forward positioning of the tongue and which results in greater airway dimensions. Grauer et al[15] evaluated the differences in airway shape and volume among subjects with various facial patterns & concluded that naso-oropharyngeal dimension differences, an improvement in the skeletal relationship may benefit naso-oropharyngeal airway dimensions, as well as improve the facial profile and dentoalveolar relationships. [Fig.3]The term "adenoid faces" or "long face syndrome" was coined by C.V Tomes[16] in 1872 who described it as long, lean, open-mouth dumb faced patients with presence of dental crowding, narrow V-shaped maxillary arches, low tongue position and high arched palate with chronic nasal airway obstruction. The most common cause of nasal obstruction in children is hypertrophy of the adenoids (nasopharyngeal pad of lymphoid tissues). [Fig.4] The adenoids enlarge and eventually out strip the growth of the nasopharyngeal space at 3-5 years, thereby reducing the nasopharyngeal size, which later increase as there is expansion of the bony nasopharyngeal space due to the maxillary growth[17]. Fields et al[18] mentioned that patients with long face syndrome had significantly less nasal air flow than the normal control group, but their respiratory volume and smallest cross-sectional area are similar.

Mouth breathing was defined by Sassouni[19] as habitual respiration through the mouth instead of nose. Breathing can be divided into three types Obstructive, Habitual & Anatomic. Airway obstruction, resulting from nasal cavity or pharynx blockage, leads to mouth breathing, which results in postural modifications such as open mouth, lowered tongue position, clockwise mandible rotation and head posture. Linder-Aronson and Leighton's[20] comprehensive investigation reported that the size of the nasopharynx and adenoids were related to history of a mouth breathing as well as to the measurement of nasal airflow. They concluded that adenoids lead to mouth breathing primarily in children with anatomically small nasopharynx.

Obstructive sleep apnea and Airway

Obstructive sleep apnea (OSA) is a common yet unrecognized sleep disorder characterized by recurring collapse of the upper airway during sleep, resulting in sleep fragmentation and oxygen desaturation[21]. OSA is multifactorial with age, gender and body mass index (BMI) as predisposing factors[22]. Primary symptoms of OSA are loud snoring, excessive daytime sleepiness, nightly choking, gasping, nocturia, morning headache, memory loss, decreased concentration & increased irritability[23]. Continuous positive airway pressure (CPAP) is the gold standard treatment for OSA which is to pneumatically splint open the upper airway during sleep [Fig.5]. Unfortunately, the acceptance, tolerance, and adherence to CPAP are often low among the patients, thus reducing the effectiveness of the treatment. Patient compliance and long-term acceptance is also low with CPAP[24]. Mandibular advancement device [MAD] is the main non-CPAP treatment in adult OSA patients which is a removable, intraoral dental splint used to protrude the mandible in a forward position and therefore enlarging the upper airway. MAD has been proven to be effective in reducing the apnea–hypopnea index (AHI) in patients with severe OSA [Fig.6]. MAD is indicated in severe OSA patients who have failed adherence to CPAP[25]. Tongue Retaining Devices (TRD) is a type of oral appliances designed to improve upper airway configuration and prevent collapse through alteration of jaw and tongue position by holding the lower jaw in a more anterior position. TRDs is an extra-oral flexible bulb and hold the tongue forward by suction, preventing its collapse into the airway[26].

Cleft lip and palate and Airway

Cleft lip and palate (CLP) is the most common congenital craniofacial malformation, occurring in 1:700 births[27]. Children with cleft lip and palate (CLP) are seen to have reduced airway size & large adenoids, which might lead to different characteristics in the upper airway and surrounding tissues from both morphological and functional perspectives[28]. Parents of children with CLP have often reported that their children snore and breathe noisily during sleep, and patients with reduced nasal airways are also predisposed to mouth breathing. Nasopharyngeal insufficiency is a major functional problem in patients with CLP. Celikoglu et al[29] assessed the nasopharyngeal and oropharyngeal sizes and total airway volume of CLP patients using cone beam computed tomography (CBCT) and concluded that these sizes were smaller in CLP patients than in normal individuals [Fig.7A & 7B].

Effect of Orthodontic Treatment on Airway Dimensions

A. Extraction and Airway: Orthodontic treatment usually indicates extraction of four first premolars followed by retraction of anterior teeth in the extraction space. Orthodontic camouflage treatment encroaches on the tongue space due to a reduction in the arch length. Some clinicians theorize that by closing extraction spaces, the maxilla and the mandible retrude, resulting in constriction of the oro-pharyngeal airway[30]. Studies done by Zheng et al[31] & Germec-Cakan et al[32] reported that reduction in the oropharyngeal airway volume & increase in flow resistance of the entire airway as well as at the oropharyngeal and hypopharyngeal levels correlated with upper incisor retraction. It also influences the pharyngeal airway posterior to the level of soft palate, uvula, and tongue in adults. The hyoid bone has shown to move posteriorly and inferiorly following retraction of anterior teeth[33].

B. Expansion and Airway: RME has been used as a routine clinical procedure in orthodontics, with its main purpose to expand the maxilla in young patients who had transversal maxillary constriction and deep palatal vault and accompanying cross-bite and crowding[34] [Fig.8]. RME is capable of increasing the skeletal nasal cavity volume by about 0.08 to 0.10% of the pre-expansion volume. RME treatment caused significant increase in upper, middle, and lower airway compartment volumes. Also there is increase in lower base-line airway volumes of the middle and lower compartments associated with greater increase in SpO2. It was also found to significantly improve the quality of life of mouth-breathing patients[35]. Timms[36] reported that 82% improvement occurred in upper airway infections after RME. Surgically assisted rapid palatal expansion (SARPE) is the alternative for adult patients requiring widening of the maxilla surgically. SARPE produced a substantial short-term increase in nasal volumes but had no effect on oropharyngeal volumes in non-growing patients[37].

C. Functional Appliance and Airway: Short and deficiency in the anteroposterior position of the mandible is very common in Class II malocclusion subjects. Myofunctional appliances are the choice of treatment where Class II skeletal pattern is due to retrognathic mandible. These appliances reposition the tongue and mandible to a new position leading to different changes in airway dimensions. Increase in pharyngeal airway space by mandibular advancement may prevent Sleep Disorder Breathing problems in adulthood[38]. Muto et al[39] identified a significant relationship between the posterior airway space and the position of the maxilla, mandible, and soft palate. Different removable & fixed Myofunctional appliances are used for correction of Skeletal Class II malocclusion. Myofunctional Appliances improve breathing during sleep and may decrease the apnoea-hypopnea index (AHI) by approximately 50% in adults and 62% in children. Removable appliances include Activator, Bionator, Twin Block & Frankel Regulator for correction of retrusive mandible & headgear for limiting growth of maxilla. A significant change was seen in the airway due to the repositioning of the mandible, especially with removable functional appliances [Fig.9]. Studies shown with Activator showed no significant effect on nasopharynx but showed improvement of oropharyngeal airway seen at the level of middle pharyngeal space[40]. The correction of mandibular retrognathism with a Twin Block appliance in growing patients not only improves the facial profile and inter-maxillary relationship but also increases upper airway dimensions thus reducing the risk of future respiratory problems. Twin Block appliance improve the treatment for airway obstruction, which mostly occurred in the oropharynx suggesting that the patency of the oropharynx can be attributed to a forward repositioning of the tongue and soft palate with the mandibular advancement. There is increase in hypopharynx following the forward movement of the hyoid bone after twin block treatment[41]. According to the review publish in APOS significant increase in the depth of hypopharynx was seen following mandibular advancement by twin-block appliance. This improvement in the dimension of hypopharynx following advancement of mandible was due to forward position of tongue and repositioning of the mandible[42]. Study done by Atik et al[43] compared the changes of pharyngeal airway after treatment with Frankel-2 and X-bow revealed significant increase in nasopharyngeal airway & no change in oropharyngeal airway. Powerscope and Forsus-fixed functional appliance therapy are used for skeletal correction of Class II malocclusion in non-growing patients. There is an increases in anterior facial height which related in increases in upper posterior airway width. Whereas, increase in posterior facial height and the mandible's forward displacement results in increase in pharyngeal airway volume thus preventing OSA and other respiratory problems[44].

D. Orthognathic Surgery and Airway: Orthognathic surgeries are focused on the treatment of severe syndromic facial malformations. Skeletal Class II malocclusion featuring mandibular deficiency is considered to be a risk factor for sleep disorders that result from oropharyngeal airway deficiency. Mandibular advancement (MA) and mandibular advancement & maxillary setback (MAMS) are two commonly used treatment modalities for mandibular retrognathia and/or maxillary prognathia[45]. Maxillomandibular advancement (MMA) surgery is a well-established surgical alterative for the treatment of obstructive sleep apnea syndrome (OSAS), as it can change the airway morphology, reverse a long, narrow, and circular airway, and consequently increase the airway reported[46]. Hernandez-Alfaro et al[47] described an increase of 78% in the volume of the airway. Study done by Achilleos et al[48] (2000) reported increase in oropharyngeal space noted in short term study whereas, there was significant increase in retrogossal space at the base of tongue in sagittal direction in both short & long term studies suggesting mandibular advancement osteotomy could increase the airway patency & can be considered as treatment approach in patients with sleep apnea. combined orthodontic and orthognathic surgical therapy has proved the most effective for the treatment of skeletal class III malocclusion when it comes to enhancing function and aesthetics. Skeletal changes caused by the surgery, however, can alter the positions and traction of the surrounding soft tissues, tongue, soft palate, hyoid bone and muscles, and also has shown to change airway volume and the size of oral and nasal cavities. The alteration of the antero-posterior position of the mandible effects the position of the hyoid bone and pharyngeal airway space[49]. When the mandible is surgically retracted, pharyngeal airway may narrow, increasing the risk of obstructive sleep apnea. Liukkonen et al[50] reported that airway size decreased at oropharyngeal and hypopharyngeal levels after mandibular setback surgery. Double jaw surgery benefit as an extended head posture leading to a relieved airway and consequently, no changes occur at posterior pharyngeal airway space post-surgery. Jakobsone et al[51] reported that, clinically, a maxillary advancement of more than 2 mm would increase the dimensions of the nasopharyngeal area and can compensate for a decrease in the PAS caused by the mandibular setback. Bimaxillary advancements greater than 10 mm are considered effective to improve OSA[52]. According to meta-analysis BSSO shows less change in the PAS after mandibular setback surgery compared to IVRO. Furthermore, a combination of LeFort I osteotomy and BSSO should be considered in patients with mandibular prognathism who have factors predisposing them to the development of OSA to reduce the amount of mandibular setback and to avoid the development of postoperative OSA[51] [Fig.10].

E. Distraction Osteogensis and Airway: Craniofacial microsomia (CFM) is the second most common congenital craniofacial malformation reportedly occurring in between 1 in 4000 and 5600 live births. Congenital Micrognathia and glossoptosis are most commonly seen in patients with Pierre Robin sequence (PRS) but may also be associated with disorders such as Treacher Collins syndrome, Nager syndrome, and hemifacial macrosomia[53]. Distraction osteogensis (DO) is a relatively less invasive surgical technique which stimulates the native bone to expand in its dimension by vector control and has been reported to be a successful treatment modality in the management of OSA. The procedure also eliminates the need for bone grafting, less surgical dissection, and high degree relapse rates that are often associated with jaw advancement surgeries. DO is a powerful tool for surgical reconstruction of complex jaw deformities. The goal of treatment in infants with severe micrognathia is to focus on breathing and feeding and to optimize growth and nutrition. It appears to be the superior method of reconstruction technique when performed correctly and effectively lengthens the jaws without the use of grafts[54]. Mandibular DO was highly successful for relief of upper airway obstruction in neonates with PRS and in older children with micrognathia and OSA. Genecov et al[55] showed that DO prevented tracheostomy in 96% of patients and allowed for resumption of oral feeding in 91%. Polysomnographic studies documented a reduction in the apnea-hypopnoea index in all infants, although there is presence of mild degree of airway obstruction due to pharyngomalacia in some patients.

Conclusion

Knowledge about airway in orthodontics gives us an opportunity to not only improve appearance, but also to improve our patients' health & everyday lives. Hence it is important for an orthodontics to have a thorough knowledge of airway anatomy & physiology and an understanding about how the airway gets affected by the treatment we provide.

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Legend Figures

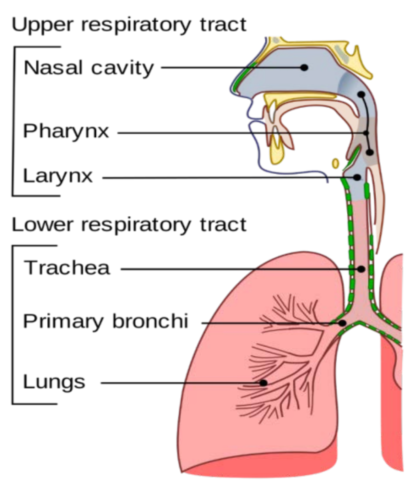

Fig. 1: Upper & Lower Respiratory Tract

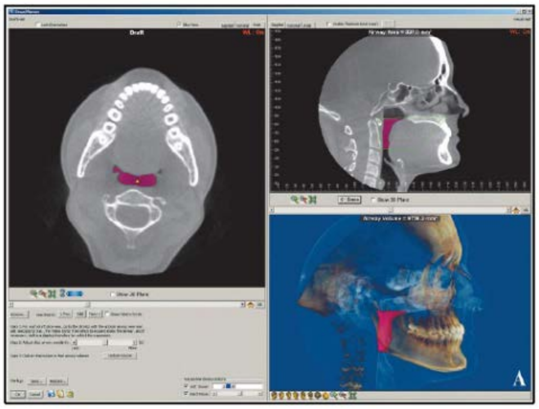

Fig. 2: 3-D CBCT Imaging Showing Different Sections of Skull Which Are Used for Assessment of Upper Airway.

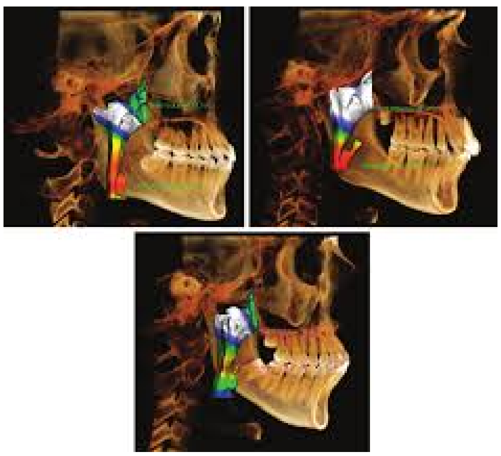

Fig. 3: Airway in Different Facial Types

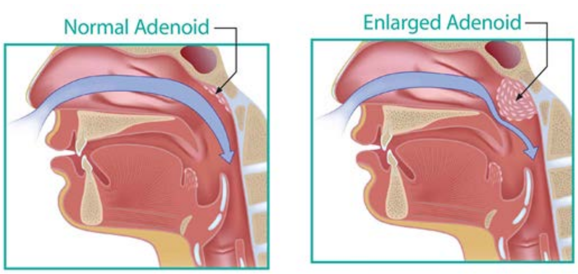

Fig. 4: Enlarged Adenoids & Airway

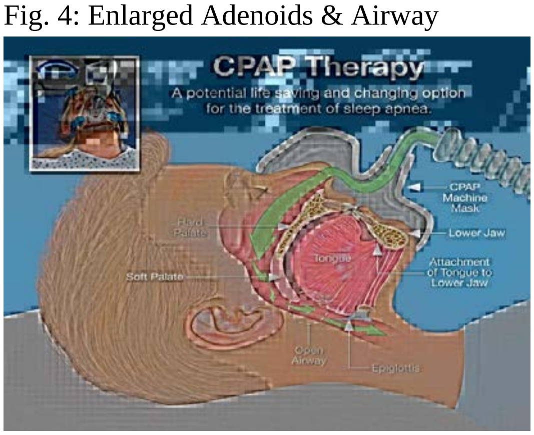

Fig. 5: Continuous Positive Airway Pressure

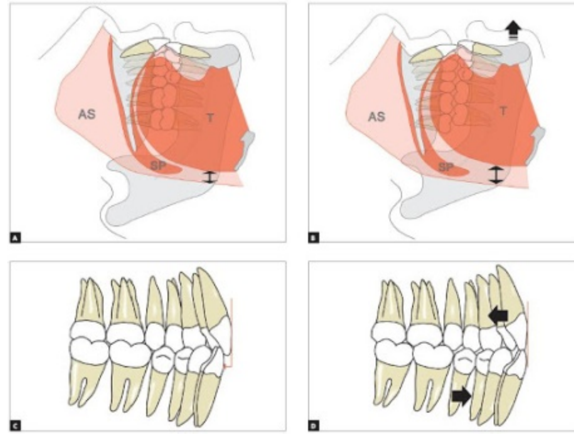

Fig. 6: Side Effect of MAD on Dentoalveolar & Skeletal Structure

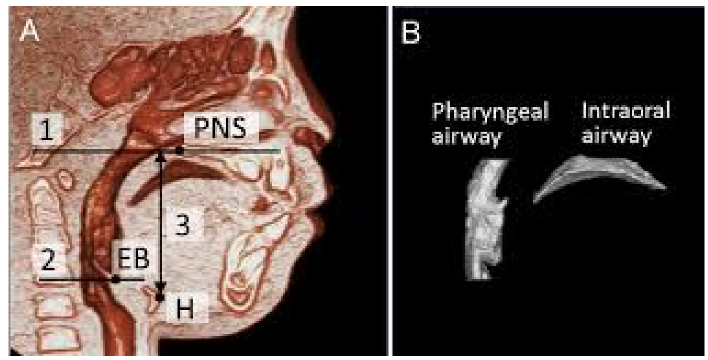

Fig. 7: A. Lateral View of Face Showing Impaired Development of Craniofacial Structures in Cleft Patients.
B. 3-D Volumetric Structure of Pharyngeal & Intraoral Airway.

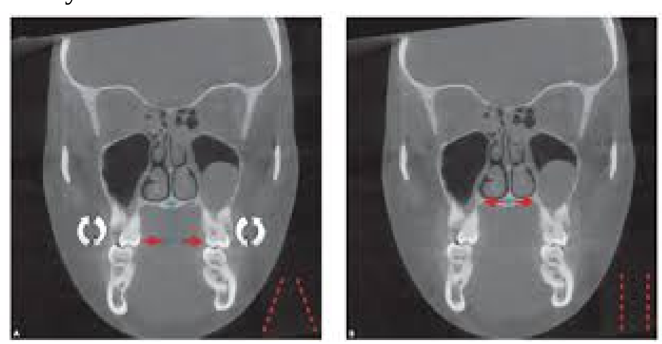

Fig. 8: Transverse Section Showing Effects of RME

Fig. 9: Improvement in Airway Post Functional Therapy

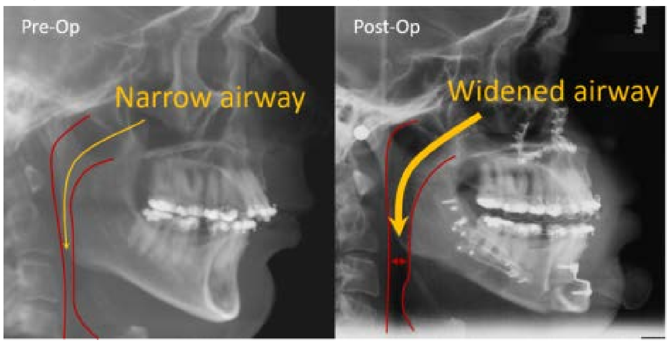

Fig. 10: Effect of Maxillomandibular Surgery on Airway