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Impact of different dentofacial orthopedic and orthognathic therapy approaches on pharyngeal airways

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Abstract

The diagnostic and treatment planning of orthodontics heavily depends on the function of breathing. Numerous studies have documented significant correlations between dentofacial, craniofacial, and pharyngeal anatomy. The link between mouth breathing and a narrowed airway that results in obstructive sleep apnea has been highlighted by numerous writers. Correcting either oral or bone issues, or both can eliminate related symptoms. It would be highly interesting to understand how the airway changes in size during orthodontic treatment by utilizing different treatment methods to comprehend and interpret the airway during diagnosis and treatment planning. Therefore a complete understanding of the concept of airway should be considered important. This chapter gives us an insight into the intricate detailing of how the various orthodontic and dentofacial orthopedic treatment signifies the changes in the dimensions of the pharyngeal airway.

Keywords: Pharyngeal airway; Skeletal changes; Dental changes; Functional appliances; Orthognathic surgeries; Palatal expansion

1. Introduction

Orthodontics is a specialty profession that has always aimed to correct dentofacial aesthetics, which includes establishing proper oral function, a healthy jaw connection, and proximal and occlusal contact between teeth. The most fundamental component of performance and function, however, is respiration, or breathing, which is the most vital human function. A precise tongue and nasal breathing position is necessary for optimal health and facial development. Thus, the current procedures in orthodontics—preventive, interceptive, or corrective—account for the urgent requirement to increase the pharyngeal airway space in addition to improving the smile and facial features.[1] Airway, breathing pattern, and craniofacial features are all so intertwined during growth and development that form can follow function and function can follow form. Respiratory impairment due to airway obstruction results in craniofacial deformity. However, aberrant craniofacial morphogenesis can result in prolonged mouth breathing, poor nasal breathing, airway blockage, sleep apnea, sleep disorders, and long-term health problems.[2] The mouth cavity and nasal cavity grow in size when the maxilla travels forward and downward. During childhood development, the rates of growth of soft and hard tissues differ. For example, between the ages of four and six, the adenoids and tonsils are the largest. Due to the involution of the lymphoid tissue, which shrinks in size after the age of twelve, as well as the simultaneous rise in vertical skeletal growth, the upper airway capacity increases during adolescence. The upper airway also undergoes morphological changes during adolescence, growing larger in the transverse dimension and becoming more elliptical overall. The airway's length and capacity typically rise until the age of 20, remain constant until mid-adulthood, and then gradually shrink after the age of 50.[3] The pharyngeal airway is located between the mandible and thyroid

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cartilage and is connected by muscles and ligaments to the surrounding structures. It supports the tongue and acts as a point of attachment for tongue muscles, primarily functioning as an anchor to aid in tongue movement and swallowing. The hyoid bone adapts to anteroposterior changes in the head and changes in mandibular position. The change in position of the hyoid bone is determined by the conjoint action of supra and infra-hyoid muscles and the resistance provided by the elastic membranes of the larynx and trachea. The ratio between the soft palate and pharyngeal space is mandatory for correct speech and to prevent sleep apnea in later life.[4] The various orthodontic treatment modalities can affect the airway by changing one or more components of the stomatognathic system. The pharyngeal airway is situated between the thyroid cartilage and the jaw, and it is joined to the surrounding structures by muscles and ligaments. It serves mainly as an anchor to facilitate tongue mobility and swallowing, supporting the tongue and serving as a point of attachment for tongue muscles. The hyoid bone adjusts to shifts in the mandibular position and anteroposterior head movements. The combined action of the supra- and infra-hyoid muscles and the resistance offered by the elastic membranes of the larynx and trachea govern the shift in the position of the hyoid bone. Proper speech and the avoidance of sleep apnea in later life depend on the soft palate to pharyngeal space ratio. Today In the interdisciplinary team therapy of diseases related to the airways and sleep, orthodontists are indispensable. With the advent of sleep medicine as a specialty, transformational or developmental biology and medicine have become much more clearly understood. The size and spatial orientation of the jaw has emerged as key components in maximizing upper airway physiology. During growth and development, breathing patterns, airway passage, and craniofacial creation are all so intertwined that form follows function. Therefore, orthodontics is a specialization that is well-balanced to treat both adults and children with optimum form and function, optimizing function for life. In orthodontics, the traditional approach has always placed a high priority on tooth aesthetics. This approach rarely attends to symptoms; hence, the airway is neglected. Consequently, to treat sleep disorders of the breathing, greater attention needs to be paid to physiologic adaptations and muscles.[5] Different outcomes from therapeutic extractions performed for orthodontic or orthognathic treatment can be attributed to different types of malocclusions, different extraction techniques, and anchoring considerations. 6 As a person ages, rapid maxillary expansion, which attempts to increase the maxilla's transverse dimension, also affects nearby areas, particularly the nasal cavity and nasopharynx.[6] By moving the jaw forward and drawing the surrounding structure with it, functional appliances help to expand the size and volume of the pharyngeal airway.[7] Orthognathic operations are performed on adults to address severe skeletal malformations. The most beneficial procedures for the airway are mandibular advancement surgeries or combined maxillomandibular advancement surgeries. However, caution must be used when considering procedures for maxilla mandibular setbacks. This article emphasizes the impact of dentofacial orthopedic treatment options and orthodontics on the airway, which can serve as a useful tool to underscore the need to take the airway into account when designing a strategic orthodontic treatment plan.

2. Anatomy of Airway

The organs in the respiratory tract that permit airflow during ventilation are referred to as the airway. They proceed through the buccal aperture and nares until they reach the alveolar sacs' blind end. To carry out distinct tasks, the respiratory system is divided into multiple regions, organs, and tissues. The upper and lower airways, which are separated by the airway channel, each have many compartments.

The pharynx is the mucosal-lined portion of the airway that is situated between the base of the skull and the esophagus. It is subdivided as follows:

- **Nasopharynx** [rhino-pharynx], is the muscular tubular structure from the nares, including the posterior nasal cavity, that divides from the oropharynx by the palate and lining the skull base superiorly.
- **Oro-pharynx** is the region that joins the nasopharynx and hypopharynx. It is the region situated between the palate and the hyoid bone, which anteriorly gets divided from the oral cavity by the tonsillar arch.
- Hypopharynx is the region that connects the oropharynx to the esophagus and the larynx, the region of the pharynx below the hyoid bone

The soft palate is the boundary between the nasopharynx and the oropharynx, while the epiglottis represents the barrier between the oropharynx and the laryngopharynx. The mucosal tissues make up the top and bottom of the soft palate, which is hanging at the posterior corner of the hard palate. The muscles, aponeurosis, blood vessels, nerves, lymph, and mucosal tissues make up the central region of the soft palate. The soft palate develops posters-superiorly and divides the nasopharynx and oropharynx during the deglutition and injection processes. The strong musculature of the mandible is related to the tongue, soft palate, and hyoid bone. Thus, the size of the pharyngeal airway space can be influenced by the mandible's placement.[8]

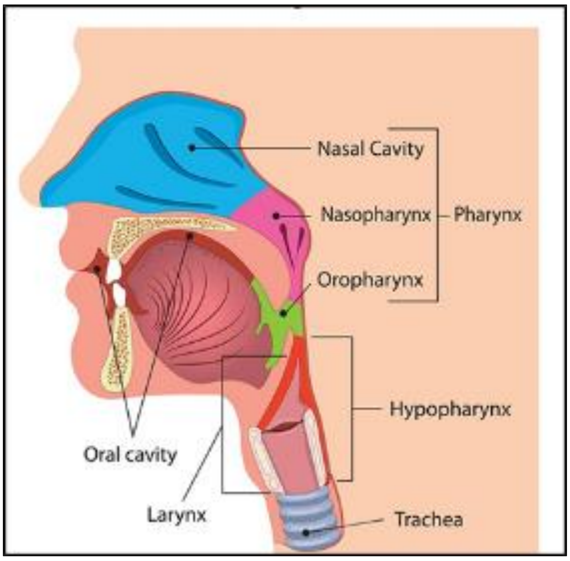

Figure 1 Anatomy of the pharyngeal airway space

3. The Impact of Different Orthodontic Treatment Approaches

3.1. Extraction Therapy

Since there are fewer soft tissue changes in a non-extraction scenario, the airway capacity decreases negligibly and the results seem to be more stable. The hyoid directly influences the hypopharynx, which in turn influences the oropharynx. This relationship can be explained by the anatomical dependency of the hyoid on the hyoglossal muscle.[9]

3.2. Two main factors influence the airway concerning an extraction protocol:

- Large retraction of the anterior teeth.
- Mesial movement of molars.

A significant retraction of the incisors caused the anterior boundary of the oral cavity to migrate dorsally. This movement may have caused the tongue to move backward, compressing the soft palate and restricting the upper airway. Furthermore, following orthodontic extraction, a decrease in the middle and inferior airway gaps has been noted in the highest anchorage group. The hyoid bone's dorsal migration is a plausible reason for the decrease.

Conversely, deliberate migration of the molars mesially and loss of anchoring create more room behind the tongue, perhaps improving the dimensions of the upper airway. Following treatment, there was an average 1.5 mm increase in upper airway space with minimum anchoring cases. This increase may have been caused by the molars' 3 mm mesial displacement following the correction of anterior crowding in the minimum anchorage group. The vertical airway length appeared to significantly increase following the extraction of the second premolar.[10]

Between the ages of six and nine, the posterior pharyngeal wall changes more quickly. There is a noteworthy association between various sagittal and vertical skeletal forms and the upper airway. Mandibular prognathism results in the largest upper airway in persons with typical vertical facial patterns; this is followed by the normal mandible and mandibular retrognathism. The hyper-divergent group has a smaller anteroposterior pharyngeal dimension than the normo-divergent group in people with a normal sagittal face pattern. The dimension decreases while the mandibular plane angle increases. No net change has been seen in teenage participants after extraction, albeit the effect of extractions on the upper airway may have partially obscured the airway's rapid expansion.[11]

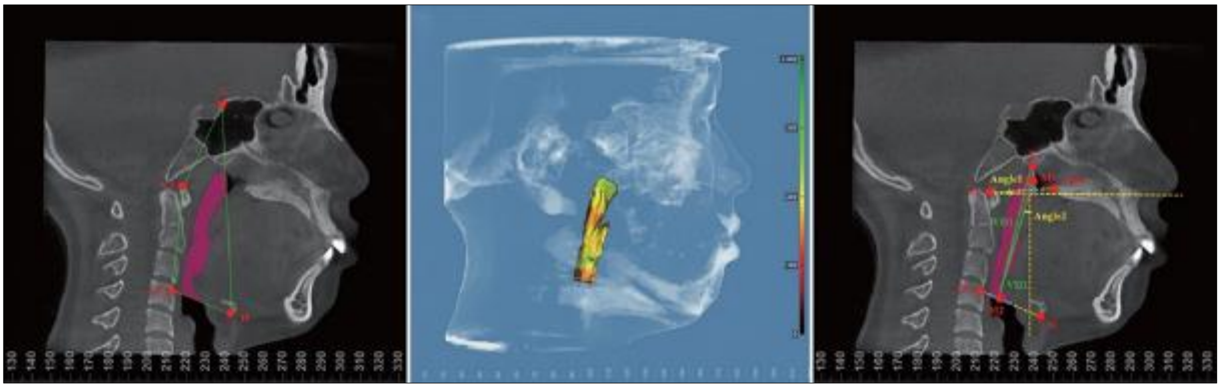

Figure 2 (a) The pharyngeal airway range was defined by four stable anatomical landmarks: points S, C1, C4, and H; (b) the pharyngeal airway was reconstructed in 3D, and the cross-sectional area and volumetric measurements were automatically calculated; and (c) Cephalometric linear and angular measurements of the pharyngeal airway measurements.[16]

Consequently, while analyzing the impact of orthodontic extractions on the upper airway in adolescents, growth patterns and age should be taken into account. Adults, on the other hand, have a cessation of upper airway expansion, with minimal variation in the degree and pattern of growth.[12] An additional factor to consider is malocclusion. In class III cases of mandibular prognathism, airway volume reduces following extraction. In class III camouflage or surgical instances including mandibular prognathism, making an extraction decision is crucial because the tongue may move backward and upward, occupying the posterior space of the upper molars and compromising the anterior wall of the pharyngeal airway.[13] A reduction in upper airway volume was observed with the posterior-inferior migration of the hyoid bone in cases of Class I bimaxillary protrusion that was extracted following extensive retraction of the anterior teeth. In Class I malocclusion crowding cases that had all four premolar extractions underwent little to no influence on the anterior oral border due to the mesial displacement of molars following crowding relief. Despite extraction in both situations, the opposing results were the product of different biomechanics.[14] The potential impact of reduced airway size on sleep quality and increased vulnerability to obstructive sleep apnea is still unclear. Consequently, a case-by-case assessment is required before developing a treatment plan, ideally in conjunction with additional diagnostic techniques such as polysomnograms (PSG) before extraction or retraction and following therapy to ensure no harm has been done.[15] According to Fang et al, There were changes in vertical liner and cross-sectional area across the various anteroposterior skeletal groups; on the other hand, there was no significant difference in the volumetric or angular measurements. It was noted that Angle II appeared to describe how the pharyngeal airway is oriented. Additionally, it was shown that Angle II and ANB had a favorable association. The more retrusive the mandible was, the more backwardly slanted the pharyngeal airway was about the orientation of the airway shape aligned with the anteroposterior skeletal patterns. Except for the vertical liner and cross-sectional area measurements, four orthodontic treatments for premolar extraction had little effect on the volumetric and angular dimensions of the pharyngeal airway (Fig 2). Four orthodontic treatments for premolar extraction may have a good impact, according to an intriguing trend in the gold standard.[16]

3.3. Rapid Maxillary Expansion (RME)

The lateral walls of the nasal cavity are displaced during the prepubertal and pubertal growth periods as a result of the mid-palatal suture opening. RME straightens the nasal septum and lowers the palatal vault. This remodeling results in a decrease in head elevation, an increase in nasal volume, a decrease in nasal resistance, and an increase in nasal airflow, all of which suggest improved nasal breathing and less mouth breathing. With the aid of acoustic rhinomanometric measurement, these results have also been verified in additional investigations. Even after a year of follow-up, the morphologic and postural modifications persisted.[17] The location, severity, and source of the nasal obstruction will all have a significant impact on how RME affects the nasal airway. RME has variable effects on the nasal cavity, with less and less of a change in nasal dimensions occurring in the posterior nasal cavity. Keep in mind that airflow varies inversely as the fourth power of the radius of the tube it passes through, even though the actual increase in basal width is minimal. It is not appropriate to open the mid-palatal suture to promote nasal permeability unless the obstruction is demonstrated to be in the lower anterior nasal cavity and is accompanied by a relative maxillary arch width deficiency.[18]

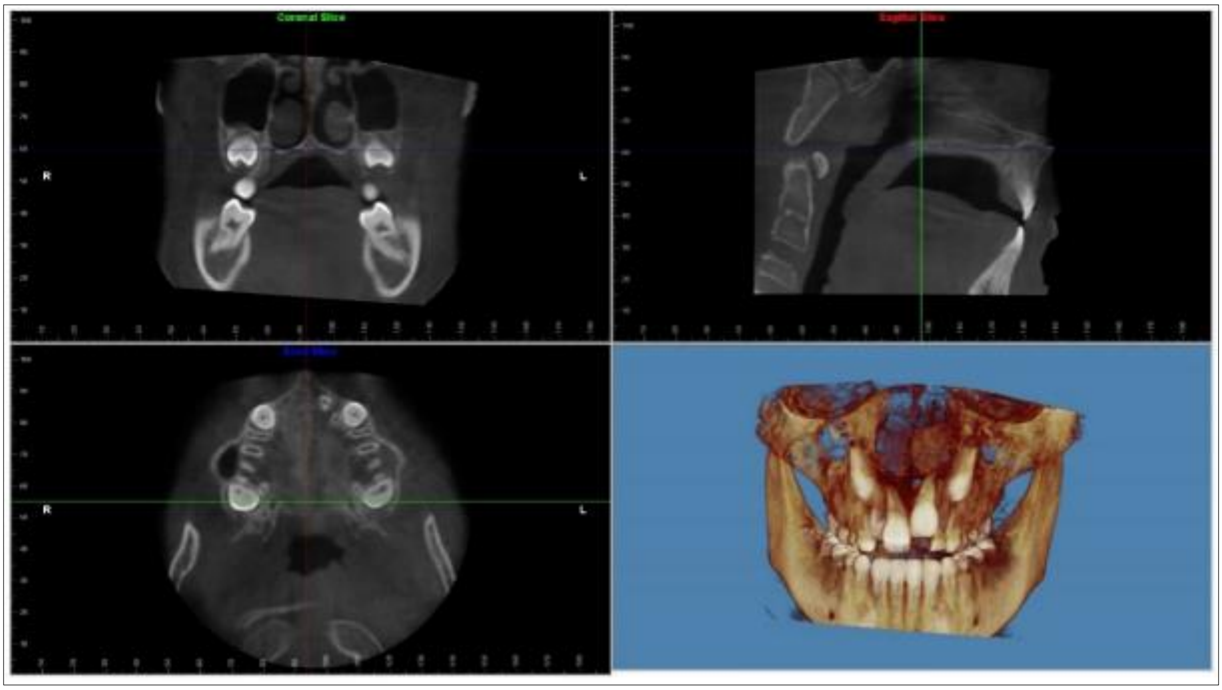

Figure 3 CBCT orientation: position the patient in the axial view such that the coronal plane is aligned with the left and right larger foramen palatine, as well as with the floor of the inferior turbinate. the axial plane's orientation with the palatal plane in the sagittal view and the sagittal plane's orientation with the mid-palate in the axial view.[24]

Maxillary constriction contributes to the pathogenesis of obstructive sleep apnea and is linked to low tongue position (OSA). Compared to healthy adults, subjects with obstructive sleep apnea had reduced airway cross-sectional areas (90-360 mm2)[19]. The apnea-hypopnea index decreased in a follow-up trial of children with OSA treated with RME, and there was a mean maxillary width expansion of 4.5 mm RME may be a modest functional improvement based on bony expansion rather than mucosal change, according to another study that used computed rhinomanometry to detect a progressive decrease in the inspiration and expiration resistance but found no significant difference for the minimum cross-sectional area at the level of the nasal valve and turbinate. A considerable rise in the cross-sectional area just posterior to the hard palate decreased further down, possibly as a result of soft tissue adaptation, along with the bony expansion. They concluded that the impact on the upper airway decreased with increasing distance between the airway part and the maxillary suture.[20] Following the Micro Implant-Assisted Rapid Palatal Expander (MARPE) treatment, the nasopharyngeal volume increased. Hybrid Hyrax expanders produced higher total airway gains in pre-peak patients than traditional Hyrax expanders[21]. Furthermore, following expansion, the nasal cavity's volume and its anterior and middle cross-sectional areas both considerably expanded. The impact persisted during the young adults' 1-year follow-up visit. Therefore, RME may increase the minimum cross-sectional area and airway capacity; however, there may not be a significant net gain in these parameters due to the associated drop in the compensatory head posture.[22]

The fan-type expansion employing the Distraction Osteogenesis Maxillary Expansion (DOME) or Surgically Assisted Rapid Palatal Expansion (SARPE) treatment would be chosen for Nasomaxillary Complex (NMC) expansion targeting the nasal floor and nasal cavity. Additionally, a favorable tongue upward posture made possible by maxillary surgical extension leads to a larger posterior pharyngeal airway. For individuals with OSA who have nasal blockage, this method would be recommended.[23] A study conducted by Tsolakis et al that there were statistically significant differences in the airway volume measurements at all time points. More specifically, the airway volume appears to be increased immediately after the expansion is completed. Six months later, the difference between the pre-treatment airway volume is significantly increased, but it seems to be decreased when we compare it to the airway volume immediately after the expansion is completed. (Fig 3) This could be happening because, in the T2 time point of expansion, the airway analysis could include an area of the opened palatal suture that in the T3 time point could be a bony structure. The minimal cross-sectional area was increased immediately after the expansion was performed, and it remained stable 6 months after the expansion. Those results suggest that palatal expansion could benefit respiratory disorder treatment when the obstruction is located in the nasal passage anatomical area.[24]

3.4. Orthognathic Surgeries

One popular treatment option for dentofacial abnormalities is orthodontic surgery. It significantly alters the architecture of the pharynx and shifts the positions of the facial skeletal elements. Any intended movement of the jaws by orthognathic surgery affects structures including the soft palate, tongue, hyoid bone, and several surrounding tissues since they are linked to the maxilla and mandible either directly or indirectly. This results in changes to the pharyngeal area's size.[25]

3.4.1. Mandibular Setback Surgery

The posterior-inferior repositioning of the hyoid bone, which carries the tongue's root lower, results after mandibular setback surgery. Cervical hyperflexion was found throughout long-term follow-up, indicating that changes in head posture may also be the cause of the hyoid bone's positional modifications. The soft palate's length of contact with the tongue increased while its thickness shrank. In the short-term follow-up, the tongue base shifted lower; over time, however, it moved upward to return to its initial position. More soft tissue area was produced by an increase in the length of the tongue and soft palate, which took up more oropharyngeal space and reduced airway patency. It has been established that one key obstructive location in OSA is the soft palate.[26]

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3.4.2. Genioplasty

During genioplasty, the tongue is pulled forward and the hyoid is suspended due to the increased stress on the genioglossus and geniohyoid muscles. The genioplasty surgical design can be altered to incorporate the genioglossus tubercle within the advancing segment and to cut further superiorly at the central area beneath the lower central incisors in patients with OSA (reverse T mandibular osteotomy).[28]

3.4.3. Maxillary Impaction

Respiratory function is negatively impacted by traditional Le Fort I osteotomy for maxillary impaction. To prevent endangering the nasal airway, maxillary horseshoe osteotomy, a variation of Le Fort I osteotomy for superior maxillary impaction, can be used. The hard palate in a horseshoe osteotomy stays pedicled on the vomer bone and nasal septum. Consequently, in a horseshoe osteotomy, the posterior nasal spine (PNS) does not shift upward. Therefore, even though the height of the face has decreased, the nasal cavity remains unaffected.[29]

3.4.4. Maxillomandibular Advancement

A forward migration of the soft palate results from the advancement of the maxilla, including PNS, which expands the oral cavity's capacity to hold the tongue. By tightening the tongue-hyoid complex, chin advancement drags the tongue and hyoid forward and causes the palatoglossus muscles to contract, straightening the soft palate. Furthermore, MMA demonstrated improvement in the lateral collapsibility of the pharyngeal wall, raising the upper airway's total capacity at all levels, particularly at the lowest cross-sectional area, and lowering the pharyngeal airway's essential closing pressure. The sagittal dimension of the pharyngeal airway increased by 47% and 76%, respectively, in the oropharynx and hypopharynx in OSA patients with hyper divergent skeletal Class II patterns. Significant AHI reduction has also been seen.[30] The effects of a mandibular setback, with or without maxillary advancement, on the development of OSA with skeletal Class III malocclusion were investigated in a Tufts University study using cephalometric and portable PSG. Given that one-jaw surgery with a movement of more than 5 mm was associated with a higher prevalence of mild-to-moderate OSA, they concluded that combined two-jaw surgery might be better for respiratory function Furthermore, it has been discovered that a substantial association exists between the amount of maxillary surgical advancement and the surgical effectiveness of MMA in skeletal Class II OSA patients, as opposed to mandibular advancement.[31]

3.4.5. Distraction Osteogenesis (DO)

Advancement of 10-45 mm of the maxillomandibular skeleton is possible with DO, resulting in 80-90% improvement in retrognathic mandibular cases. Can be effective for severe OSA with severe mandibular retrognathism and or a large amount of maxillary advancement is required.

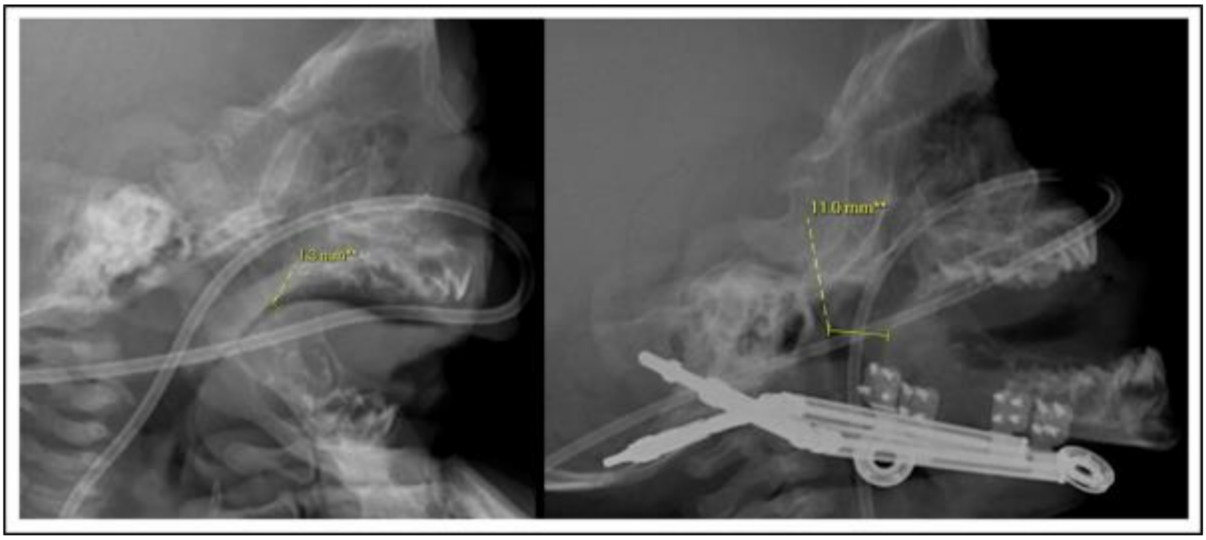

Figure 4 Pharyngeal width at the level of the tongue base was also calculated from lateral cephalograms before distraction and postoperatively

In a study conducted by Jordan et al Mandibular distraction osteogenesis (MDO) is an effective intervention to address tongue base obstruction (TBAO) in airway grade in patients with Robin Sequence (RS). Alongside polysomnography (PSG), direct laryngoscopic airway visualization is an important and assessable outcome. The analysis showed that following MDO, patients have a pharyngeal diameter at the level of the tongue base.[32]

3.5. Changes in pharyngeal airway space using functional/Orthopedic appliance therapy

Pierre Robin postulated in 1934 that neonates with mandibular insufficiency benefit from the use of an intraoral device, which helps push the lower jaw forward. This aids in avoiding oropharyngeal collapse and the posterior relocation of the tongue during sleep. With the use of various myofunctional equipment, this approach is now frequently employed in adult patients with obstructive sleep apnea (OSA) to prevent an upper airway collapse during sleep. Furthermore, the concept of moving the mandible anteriorly is used in dentofacial orthopedics to stimulate mandibular growth in skeletal Class II growing patients who have a mandibular deficit. This is achieved by the use of various myofunctional appliances. Some authors have proposed that the treatment of growing patients with short mandibles through functional orthopedics may result in larger oropharyngeal airways, while others have proposed that the likelihood of developing respiratory issues, later on, may be decreased.[33] One of the myofunctional appliances with the highest patient compliance rates is the twin block. As a result, this appliance can produce notable outcomes. When the twin block was compared to the Mandibular protraction appliance MPA, Jena et al. claim that the twin-block appliance greatly improved the oropharynx size. The dimensions of the nasopharynx, oropharynx, and hypopharynx significantly increased after twin block treatment, according to another study. The advancement of the mandible via myofunctional orthopedic correction was advantageous, even if the growth itself only slightly improved the oropharyngeal dimension. Because the functional appliances move the mandible anteriorly, the tongue is positioned farther forward, increasing the oropharynx's total size. When a detachable functional appliance (twin block) was used instead of a fixed functional appliance, the oropharynx's dimensions improved more. Following functional appliance treatment, there was an increase in oropharyngeal volume in Class II patients, which increased the upper airway's final volume.[34]

In research by Entrenas et al., individuals with mandibular Class II malocclusion who had early treatment with twin block appliances showed a significant increase in upper airway size in both the nasopharynx and oropharynx. Patients exhibiting mouth breathing, snoring, and/or clinical signs of sleep apnea-hypopnea syndrome (SAHS) were found to benefit from twin block treatment, as evidenced by the improved respiratory quality observed in all cases (Fig 5 and Fig 6). Patients with mandibular Class II malocclusion have a decrease in UA size with growth, and if functional appliances are not used to cure the condition, they may eventually develop SAHS. Twin block appliances are among the most widely used and well-liked functional appliances because of how well they can repair skeletal Class II abnormalities, which enhances the facial profile. Furthermore, these gadgets might be useful in treating kids with mandibular retrognathia and respiratory sleep disorders (RSDs), which would lower the chance that an adult will develop SAHS.[36] Compared to the participants who were not treated, the oropharyngeal airway dramatically improved with the use of the Forsus Fatigue Resistant Device (FFRD). Following the intervention, the FFRD group saw an increase of 1.06 mm in the mean values of Superior Pharyngeal Space and 1.28 mm in the mean values of Middle Pharyngeal Space. There was no discernible improvement in the hypopharynx's breadth, according to Aksu et al measurement of the airway space corresponding to the hypopharynx's depth.[35] The pharyngeal airway dimensions of Class II malocclusion participants with retrognathic mandibles are improved by functional equipment. However, it is also clear that growth is primarily responsible for the slight improvement and the minimal impact on nasopharyngeal airway passage. One of the main outcomes of functional appliance treatment is an improvement in the dimensions of the oropharyngeal airway channel. When it comes to improving the positive airway pressure (PAP) dimension, removable functional appliances outperform permanent functional appliances.[37]

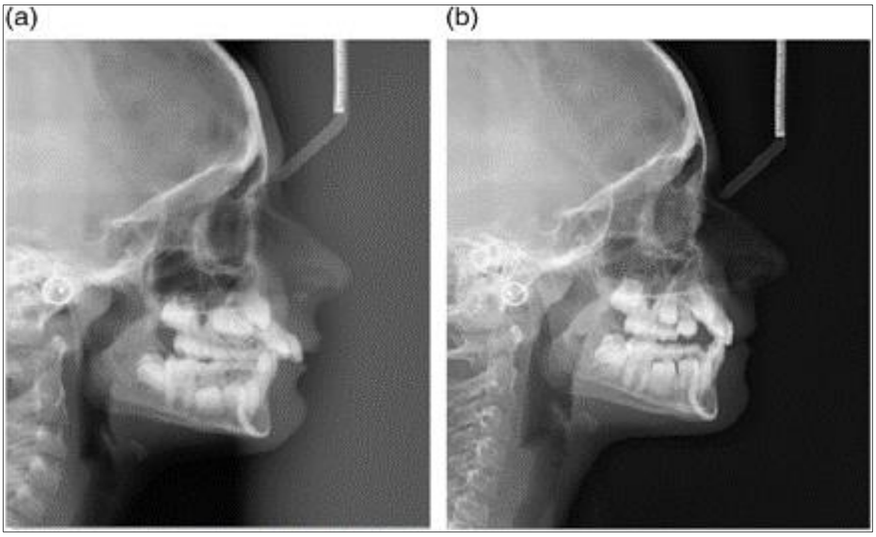

Figure 5 a) Lateral teleradiography of the skull at baseline. (b) Lateral teleradiography of the skull after 2 years of growth without treatment. A decrease in the upper airway and an increase in the tonsils are observed.[36]

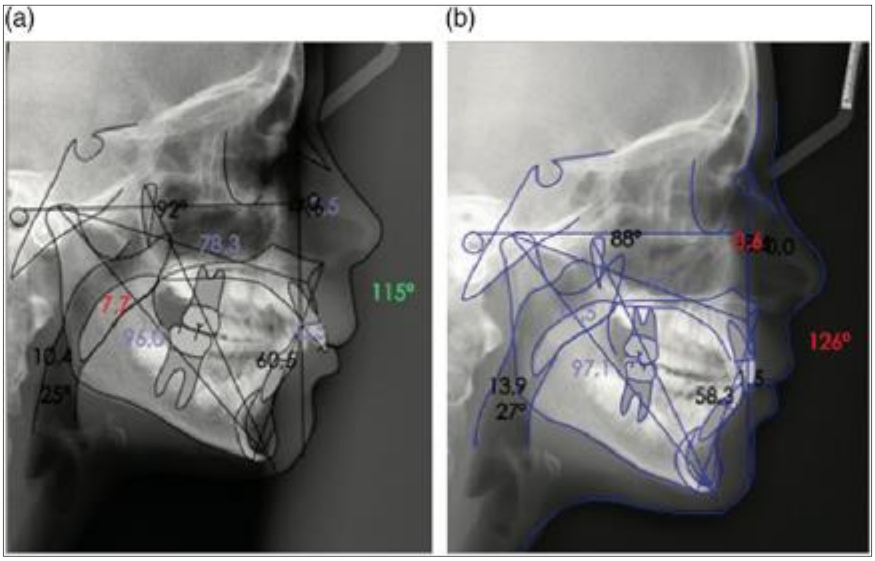

Figure 6 (a) McNamara analysis of the upper airway in a patient before Twin Block treatment. (b) McNamara analysis of the upper airway in the patient 18 months after Twin Block treatment. An increase in the upper airway is observed.[36]

4. Conclusion

One of the most important components of orthodontic diagnosis and treatment planning is the examination of the orthodontic treatment's impact on the dimensions of the pharyngeal airway. The protocol encourages the imitation of what nature intended, namely, the fitting of all teeth at an early age using a variety of expansion appliances, habit-breaking gadgets, and functional jaw orthopedics. While it is commonly recognized that maxillomandibular advancement procedures enhance dentofacial aesthetics, they also improve airway dimensions. However, because this technique is intrusive, the theoretical percentage of cases that receive this helpful treatment is much lower. Even while orthodontics now acknowledges the significance of diagnosing and treating sleep and airway issues, there is still a great deal of unexplored territory.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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