AN ASSESSMENT OF CURRENT CLINICAL ORTHODONTICS: CLINICIAN KNOWLEDGE, IDENTIFICATION AND TREATMENT PLANNING OF RESTRICTED AIRWAY

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Jennifer Mirman, DMD
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Thesis Approval(s):

James Sciote, DDS, MS, PhD ______________________
Advisory Chair, Temple University Kornberg School of Dentistry,
Department of Orthodontics

Vinodh Bhoopathi, BDS, MPH, DScD
Committee member, Temple University Kornberg School of Dentistry,
Department of Pediatric Dentistry and Community Oral Health Sciences

Jeffrey Godel, DMD, MS
Committee Member, Temple University Kornberg School of Dentistry,
Deptartment of Orthodontics

Carmen Doumit, BDS, MS
Committee member, Temple University Kornberg School of Dentistry,
Department of Orthodontics

ABSTRACT

Objectives: The naso- and oropharyngeal airways are influenced by a myriad of factors: jaw shape and position, tongue shape and position, lymphoid tissue, sleep apnea, chronic mouth breathing, and swallowing patterns. It is unknown if the relationships of these factors are recognized and routinely assessed in clinical orthodontics. This cross-sectional study sought to determine the proportion of participating orthodontists whom: 1) Are knowledgeable about airway restriction and its etiology, 2) Learned about these topics in post-graduate orthodontic education, 3) Consider airway restrictions in orthodontic treatment planning.

Methods: A survey was administered through an online survey management platform, and sent to the email listings of 2,084 active American Association of Orthodontists (AAO) members. Survey questions are evidence-based and developed from findings in current literature. The questionnaire results were analyzed by coding and cleaning data through SAS 9.3 software. Univariate and bivariate analyses were performed to assess responses.

Results: The survey received responses from 117 orthodontists. Most received their orthodontic certification from a two-year program (71.82%). The majority were knowledgeable about tongue adaptations, swallowing mechanisms, mouth breathing, and sleep apnea. Respondents were less confident about the relationship airway patency has with lymphoid tissue and with jaw position. Only half (50.51%) were taught about restricted naso- and oropharyngeal airway in post-graduate orthodontic education. A low majority, 66.32%, reported that they refer for medical consultation to the appropriate clinician before they begin treatment if a patient presents with restricted airway.

Conclusions: Although the majority of respondents are knowledgeable about factors that influence airway patency, the survey identified areas in which understanding

of and education in certain topics (lymphoid tissue, jaw position) may be lacking. Further emphasis should be placed on these topics to improve patient care. Orthodontics nationwide would benefit from more thorough post graduate orthodontic residency curriculum and general guidelines for clinical management of patients that present with airway obstruction.

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CHAPTER 1

INTRODUCTION

There are notable changes in the maxillary and mandibular jaws and dentition that increase in prevalence in patients with restricted or obstructed airway. The naso- and oropharyngeal airways are influenced by a myriad of factors: jaw shape and position, tongue shape and position, lymphoid tissue, sleep apnea, chronic mouth breathing, and swallowing patterns. Orthodontists should attempt to identify the cause to manage and treat the proper underlying etiology. Often times these etiologies are interconnected, and it is vital that the clinician is able to identify the concurrent signs.

Orthodontists across the United States have attended a post-graduate residency program. These programs educate the doctor and form the basis of each doctor's unique understanding of malocclusion and the components that play a role in development. The topic of airway has many components, and it is not noted what aspects are included in the post-graduate orthodontic curriculum.

In clinical practice, the interplay of the cranial base, maxilla, mandible, and dentition are routinely examined on the lateral cephalogram (Naini, 2011), but the assessments of the naso-and oropharyngeal airways are often overlooked. If a severe obstructed airway is observed, an orthodontist may refer the patient to an ear, nose, and throat doctor (Costa et al., 2017). Do orthodontists recognize a constricted airway, understand its etiology, and consider this in treatment planning?

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Tongue Position and Shape

The tongue is a muscular organ that is only fixed to bone on its lower border. Since it is not fixed on both sides, it therefore has less accurate positioning than other muscular organs. The sense of touch aids in this limitation, and if the tongue is touching the incisors, the body is more conscious of this positioning (Straub, 1960). It is not surprising to see that tongue position may be modified by anatomic variation, posture, or habits.

An influencing force on the development of the maxilla is the tongue. In normal development and function, the tongue postures to the palate, and exerts a buccally-directed force on the teeth and alveolus. This force is opposed by the buccinators, and the teeth become aligned within the neutral zone. In cases of mouth breathers, or other abnormal developments when the tongue is in a low resting position, the buccal force on the maxillary arch is lost and maxillary development is overpowered by strong buccinator musculature. Elongated and constricted maxillary arches result (Baker, 1954).

Straub noted that tongue position affects mandibular development, stating if the tongue is held between the teeth, as in abnormal swallowing or open bite cases, that the mandible “appears to be literally bent by the position of the tongue between the teeth (Straub, 1961).” This shape change can be witnessed at gonion, displaces the head of the condyle, or affects the length of the mandibular ramus and may result in very steep mandibular plane angles (Straub, 1961).

Abnormal physiology of the tongue can lead to malfunction and malrelationships. Spacing and tipping of teeth is often observed if a patient presents with a large and hyperactive tongue, whereas collapsed mandibular dentitions are witnessed in patients who have small or absent tongues (Dubner, 1978). Macroglossia may have an effect on the dental arch and present with spacing between the teeth and mesialization of the lower arch. Tongue thrusting at rest, on swallowing, during mastication, or in speech may result in maintenance of open bites. These anterior open bites are often retained by defective speech habits that result, as the child pushes the tongue against the lingual of maxillary incisors to create sounds such as “s,” “z,” and “th” (Baker, 1954).

Proffit (2007) explains a differing viewpoint, that it is logical to believe a sustained light pressure by the tongue against the teeth would affect tooth position, but in reality the tongue thrust swallow does not involve a prolonged force. It only involves the interaction of the tongue against the teeth for about one second per swallow. The average person swallows 800 times/day, and only a few swallows/night, which result in less than 1000 swallows/day. Proffit argues that 1000 seconds of pressure is not of long enough duration to result in an effect on the dentition. Instead, if the resting position of the tongue is forward, the pressure from the tongue is longer lasting and then may affect tooth position. This difference is in the location of the patient’s tongue at rest, and this needs to be observed. Tongue posture, not the tongue thrust swallow, may be an influencing factor in a child’s open bite (Proffit, Fields, & Sarver, 2007). As demonstrated above, there is not a definitive school of thought if tongue thrust itself can be the cause of open bites. Tongue thrust swallow, may be an adaptation to a narrowed airway and elicits activation of muscles that are not normally used in the act of deglutination. Abnormal swallow is detailed in section 2.3.2.

Mallampati (1985) correlated tongue size with pharyngeal size and his study should be acknowledged when discussing tongue shape in relation to laryngoscopy. Specifically, this system relates the base of the tongue to the faucial pillars, soft palate and uvula, classifying the largest structure in the mouth (tongue) that affects the accessibility of the laryngeal inlet. This is notable to consider in terms of airway patency. Patient airway is assessed by visualization of pharyngeal structures and is divided into three subclasses: Class I is visualization of the faucial pillars, soft palate, and uvula, Class 2 is when the uvula is masked by the base of the tongue but the faucial pillars and soft palate can be witnessed, and Class 3 is when only the soft palate can be visualized (Mallampati et al., 1985). Although this description is used in practice to predict ease of intubation, it directly correlates size of tongue with airway access. Since airway patency is dictated by the activation of the genioglossus, increased muscle activation results in narrowed airway and a high Mallampati classification is commonly seen in patients with sleep apnea (Isono, 2008). The Mallampati score has been found to be an independent predictor of obstructive sleep apnea (Nuckton, Glidden, Browner, & Claman, 2006). This index allows practitioners to discern small but significant differences in tongue size (Isono, 2008).

2.2 Jaw Position and Shape

The shape and volume of the upper airway is influenced by maxillary and mandibular growth. As the jaws grow in size, they move forward in the face and allow for an increase in airway volume (Enlow, 1996). Abnormal sagittal development has been associated with changes in airway patency. People with retrognathic mandibles and a Class II skeleton were found to have significantly smaller mean total airway volume, from the anterior nasal cavity and nasopharynx to the epiglottis, than patients with an orthognathic mandible and Class I skeleton (Kim et al., 2010). Mandibular body length was significantly positively correlated with total airway volume, whereas a significant negative correlation existed between the ANB angle and total airway volume. Nasal airway dimension was found to be influenced by skeletal pattern, with a significant increased height of the posterior nasal cavity in Class I skeletal subjects compared to Class II skeletal subjects (Kim et al., 2010). Class III subjects have been found to have significantly increased upper pharyngeal airway volume than Class I subjects (Hong, Oh, Kim, Kim, & Park, 2011). Men with a Class III skeleton had increased volume of upper pharyngeal airway, whereas women with Class III skeleton had significantly increased volumes of all airway measurements when compared to Class I men and Class I women, respectively. Lower pharyngeal airway volume was positively correlated with mandibular body length, and negatively correlated with ANB angle (Hong et al., 2011). This increase in airway volume may be a result of an anteriorly positioned mandible.

As the jaws develop vertically, it has been found that patients with posterior rotating mandibles had narrower lower pharyngeal airways than patients with normal or anterior rotating mandibular growth (Akman, Tpygar, & Wada, 2002). Hyperdivergent subjects exhibit a narrowing of pharyngeal space, in both the nasopharynx and oropharynx, when compared to normodivergent subjects (Joseph, Elbaum, Cisneros, & Eisig, 1998). This hyperdivergent group had a higher Class II skeletal discrepancy with retruded maxillary and mandibular apical bases, and posterior and inferior tongue displacement. The reduced sagittal dimension of the airway in hyperdivergent patients may be attributed to posteriorly displaced jaw relations or tongue position (Joseph et al., 1998).

2.3 Swallowing Mechanisms

2.3.1 Normal Swallow

In normal development as a child transitions from edentulous gum pads to the eruption of teeth, swallowing behavior also undergoes a change. When incisors are not present, the infantile swallowing mechanism involves the formation of a seal between upper and lower gum pads by the tongue as it protrudes between the two ridges. As development continues, incisors begin to erupt into occlusion to create a seal that replaces the need for this tongue thrust. Normal swallowing then relies on the activation of the muscles of mastication to bring the teeth and jaws together, creating the seal needed to swallow (Straub, 1960). During normal deglutition, muscles of mastication play an active role in the process, whereas the muscles of facial expression have no value. The muscles of mastication are used in bringing the teeth and jaws together, and tightly hold them together during the course of a swallow. It is important to note that normal swallowing is the only process in which the teeth are brought tightly together. Normal swallowing is defined as the process by which people whose teeth have good occlusion close their teeth firmly in maximum intercuspation. The tip of the tongue is placed on the posterior rugae in the palate, and the tongue lays on the palate. Tongue pressure is upward and backward, and as the act occurs, it moves distally (Straub, 1960).

2.3.2 Abnormal Swallow

Abnormal swallowing does not rely on the muscles of mastication to bring the teeth together, instead the tongue is thrust between teeth and the muscles of mastication bring the teeth together until they touch the tongue. Facial muscles of expression then tense and aid in forcing the bolus of food in a backwards direction. Since the initial tongue thrust may create an otherwise absent seal from the lack of incisor overlap, the patient relies on anterior positioning of the tongue and activation of orbicularis oris and mentalis muscles to seal off the oral cavity, and the process becomes a learned behavior (Straub, 1962). In patients who have abnormal swallowing, there is a facial grimace resulting from a distinct line that runs down from the lateral border of each nostril to the orbicularis oris, and lips are protruded. Holding the tongue in a forward position, between the teeth, prevents normal swallowing. Abnormal swallowing may develop from bottle fed babies that are given a bottle that has a long nipple. This theory of tongue thrust etiology was discussed by Straub and predominant in the 1960s. A long nipple on the bottle is too large for a baby's mouth, and the baby is not able to put the tongue against the roof of the mouth. This learned behavior does not eliminate itself as the child grows older and may present in adulthood, with or without dental open bites (Straub, 1960).

Straub (1961) discusses four presentations of abnormal swallowing. Group 1, with a diastema between the maxillary central incisors. There are variations in tongue shape and action that can result in this appearance. Group 2 has an open bite in the anterior and posterior regions, from the first or second molars forward. These are best treated with habit therapy and correction of abnormal swallowing habit, which may change the mandible and reposition the head of the condyle, depress the molars, or change the mandibular angle at gonion. Group 3 is the side-thrust swallow, witnessed by no occlusion in the canine premolar region. The tongue is displaced laterally, and hardest to retrain in this position. Group 4 abnormal swallow is the most difficult to detect, since it presents with a closed bite. Patients do not start treatment with an open bite, and the abnormal swallow goes undetected until after the completion of treatment when the patient then opens up and has an open bite. When the teeth are closed tightly together, Group 4 patients have a seal of the oral cavity from the interdigitation of posterior teeth and overlap of incisors. Instead of using this natural seal to create a suction, the child opens their mouth and places the tongue between teeth in order to swallow.

Abnormal swallow results in developmental changes of both the maxilla and mandible. Since the tongue does not touch or rest upon the palate, as it should in its normal postural position, collapse of the maxilla is expected and a narrow maxilla often results. Crossbite of the upper jaw influences an adverse development of the mandible as it occludes during mastication (Straub, 1962).

2.4 Lymphoid Tissue

2.4.1 Adenoids and Tonsils

During a child's prepubescent years, adenoid and tonsil tissues experience great growth. Lymphoid tissue growth (adenoids and/or tonsils) reaches a maximum at 11-13 years, with total lymphoid tissue reaching 200% greater than that of an adult (Scammon, 1930). In response, to allow for easier breathing and to create a passageway for food, the tongue may protrude forward (Subtelny, 1965). The true influence of enlarged tonsils on tongue protrusion has been debated, but if the tonsils are chronically inflamed for a period of time, it is believed a new neuromuscular pathway may be established and control maintenance of abnormal swallowing. An anterior positioning of the tongue may be witnessed when the tonsils are chronically inflamed. People with enlarged tonsils therefore may or may not become tongue-thrusters (Straub, 1962). If the inflammation lasts for an extensive period of time, it becomes painful to swallow and the normal swallowing behavior is modified. Instead of food being able to touch the tonsils, this interaction is avoided by the mouth opening and tongue moving to a more anterior position. This adaptation provides more room for the passageway of food. This positioning may develop into a learned behavior that continues after the tonsillar swelling is resolved.

Brodsky and Koch (1992) have determined a grading scale for tonsils based on the size of space they occupy in the pharynx between the anterior pillars. This scale is explained as follows: Grade 0- tonsils limited to tonsillar fossa, Grade 1- tonsils occupy up to 25% of the space between the anterior pillars in the oropharynx, Grade 2- tonsils occupy 25-50% of the space, Grade 3- 50-75% of the space, Grade 4- 75-100% of the space. Samba Diouf (2015) assessed tonsillar size with dental changes and arch perimeter lengths. Maxillary intercanine width was significantly and negatively correlated to tonsillar grade, as were the maxillary interpremolar and intermolar distances (Samba Diouf et al, 2015). Tonsillar grade was significantly and positively correlated to depth of the palatal vault. As tonsils enlarge and become obstructive, a person often adapts to mouth breathing and the tongue postures to a more depressed position. This low tongue posture does not allow the tongue to influence proper development of the maxilla, and a constricted archform with high palatal vault result. A negative correlation was also found between age of patients and tonsillar grade, which is expected and presumed by Scammons growth curve that lymphoid tissues decrease in size as a person ages (Scammon, 1930). Tonsillar grade was significantly correlated with Angle's molar classification. Grade 0 were likely to have Class I occlusion, whereas Grade 4 patients were significantly more likely to develop Class II malocclusions. Grade 3 and 4 patients were significantly more likely to develop an anterior open bite, and these patients likely resorted to mouth breathing as a way to overcome upper airway obstruction.

Cone beam computed tomographic (CBCT) analysis has been used to measure adenoid and tonsil hypertrophy in Class II versus Class III subjects (Iwasaki et al., 2017). Patients with class II malocclusions were found to have significant increase in adenoid hypertrophy incidence and significantly greater nasal restriction than the Class III malocclusion subjects. Class II subjects with inferior tongue posture were also of higher incidence than Class III subjects. The incidence of tonsil hypertrophy remained the same between groups. Class III subjects had significantly larger depths of oropharyngeal and hypopharyngeal depth. In the Class II group, nasal resistance was significantly correlated with intraoral airway volume, hypopharyngeal width and airway height. It was negatively correlated with interdental width difference of the first molars in the maxillary arch with those in the mandibular arch, increased nasal restriction presented with decreased arch width. Class II children often had features of nasal obstruction and increased adenoid size. Constriction of the maxillary dentition correlated with nasal obstruction, enlarged tonsils and an inferior and anteriorly displaced tongue. This inferior tongue position had a strong association with mouth breathing. Class II patients with anterior tongue position had an association with increased adenoid and tonsil sizes. Nasal obstruction with inferior tongue positioning was only found in half of the Class III subjects who had inferior positioning of the tongue, suggesting that in Class III patient, tongue position may be a response to mandibular position and width instead of nasal obstruction. Class III patients also were found to have a strong association of anterior tongue posture with enlarged tonsils (Iwasaki et al., 2017). The anterior positioning of the tongue may create a forward force on the anterior positioning of the mandible, causing protrusion of lower incisors, and an anteriorly displaced mandible.

2.4.2 Mouth Breathing

Greater effort is needed to breathe through the nose than through the mouth, and this increased work is acceptable up to a point. Once the nasal airway is partially obstructed, the work needed to perform nasal breathing is increased, and the patient may opt for the less demanding route of mouth breathing instead (Proffit et al., 2007). If the tonsils or adenoids become enlarged enough to restrict nasopharyngeal airway, the patient immediately becomes a mouth breather (Oliver, 1918). Adenoid tissue is the primary reason children become mouthbreathers and many developmental changes, as noted above, result from the adapted breathing pattern. There is a clear association of nasal obstruction with oral respiration and dentofacial developmental changes. Woodside and Linder-Aronson (1991) recognized the relationship and sought to examine maxillary and mandibular changes in response to adenoidectomy and reestablishment of nasal breathing. After adenoidectomy, nasal airflow improved, mandibular growth increased significantly in girls and boys, and the midface showed a small increase in growth. Although these increases were slight, this implies maxillary and mandibular growth is negatively influenced by airflow obstruction and oral respiration.

Chronic mouth breathers have been characterized as having unique orthopedic and orthodontic development due to alterations in atmospheric pressure, loss of the normal force from the tongue to shape and widen the dental arches as they form, and the lack of restraining force from the lips on anterior teeth. There is a loss of the normal atmospheric pressure during respiration and a lack of downward growth of the maxilla is noted. The nasal septum does not then have enough room to develop properly and becomes deflected. In mouth breathing, the normal action of musculature is absent on the developing dentition and face. Since the mouth is open, the tongue is brought to an inferior position preventing its influence on lateral development of the maxilla. The tongue remains in a downward position behind the mandibular incisors and remains within the confines of the mandibular teeth (Baker, 1954). This allows the buccinator muscles to exert unopposed pressure on the maxillary arch, and a narrow and constricted archform is commonly observed. The open mouth posture may allow for posterior teeth to supra-erupt, face height to increase, and cause downward and backward rotation of the mandible, ultimately decreasing overbite and increasing overjet (Proffit et al., 2007). The lips are far departed at rest, reducing the influence of the lips on the anterior dentition, and teeth procline and protrude. The lower lip is positioned behind the maxillary anterior teeth, and creates a forward force assisting the protrusion. The musculature to hold open the mandible remains active, and the downward pull may restrict the mandible's forward growth causing a discrepancy between the upper and lower jaws. The dentofacial deformities worsen and become more severe as the child matures (Oliver, 1918). Patients with a mouth breathing habit present with increased lower incisor proclination, lip incompetence, and a convex facial profile (Basheer, Hedge, Bhat, Umar, & Baroudi, 2014). Mouth breathers often present with lips parted at rest and gingivitis in the anterior segment, which is an obvious clinical identifier. For patients with a long history of mouth breathing, the integration of these signs may result in a specific facial appearance frequently identified by orthodontists as "adenoid facies." This manifestation is a sum of clinical signs such as open mouth posture, narrow alar base, increased lower facial height, narrow maxillary arch, posterior crossbite, and Class II dental malocclusion (Basheer et al., 2014).

Harvold (1981) sought to demonstrate a direct causal relationship between airway obstruction and dentofacial changes. Primate studies have revealed that nasal blockage results in oral respiration and dentofacial changes, although there was variation among the deformities noted in the experimental population. The adaptation develops from each animal seeking the most convenient way to secure airflow. Postural and developmental changes of restricted nasal airway rhesus monkeys included: 1) a relaxed open mouth breathing position, 2) upper lip notching from activation of lip elevators, 3) tongue protrusion, 4) tongue adaptations to secure airway such as thinned dorsal tongue creating passage to pharynx and median groove, and 5) narrowing of mandibular arch and decrease in maxillary arch length, 6) activation of geniohyoid and digastric muscles to lower mandible, and intrinsic tongue muscles and genioglossus to protrude the tongue. Monkeys lowered the jaw, protruded the tongue, and elevated the upper lip to secure a patent oral airway. Lowering of the jaw resulted in an increased gonial angle and steeper mandibular plane. Notching and tongue adaptations were eliminated upon restoration of normal breathing. The noted changes seen in primate experiments of restricted nasal airway resemble those changes witnessed in children as described above by Basheer et al.

(2014), both species present with a variety of appearances, from normal to severe malformation.

A recent study by Costa (2017) sought to analyze orthodontist ability to identify patients that habitually mouth breathe versus otolaryngologist ability to identify these same patients. They revealed that the orthodontists included in the study had poor recognition of mouth breathing in young patients, with correct identification of these patients ranging from 17.1-31.4%. Main issues for mouth breathers were found to be "breathing problems, open-mouth breathing, snoring, dry mouth on awakening, drinking water during the night, daytime sleepiness, and use of nasal spray." Mouth breathers due to airway restriction, as opposed to mouth breathing from habit, reported more health problems, sinusitis, tonsillitis, medical treatment, medications, speech therapy, tonsillectomy/adenoidectomy, breathing problems, stuffy nose, snoring, dry mouth on awakening. Speech therapy was more often reported by those who had mouth breathing as a result of airway obstruction than mouth breathing from habit (Costa et al., 2017). These common findings may be a valuable resource for orthodontists in questioning their patients when a mouth breathing habit is suspected and should aid as an identification tool for orthodontists.

2.5 Sleep Apnea

Obstructive sleep apnea (OSA) is a product of recurrent upper airway occlusion during sleep (Tsuchiya, Lowe, Paw, & Fleetham, 1992). The main risk factor for OSA is obesity, with strong predictors being increased BMI, central accumulation of adipose tissue, and neck circumference. Fat deposition in the neck around the pharyngeal airway is likely to lead to pharyngeal collapsibility. The prevalence is two to three times greater in men than women, and in older individuals (>65 years) than middle aged individuals (Eckert & Malhotra, 2008). Although sleep apnea is highly associated with obesity, only a small amount of overweight subjects develop sleep apnea (Tsuchiya et al., 1992). There are other predisposers for this condition aside from obesity, such as malfunction of structural and functional airway factors. Physiologic causes of OSA involve an individual's upper airway anatomy, and the ability of its dilator muscles to respond to respiratory challenge during sleep. The stability of a person's respiratory control system, the tendency to wake from increased respiratory drive during sleep, and the potential for state-related changes in lung volume all influence OSA development (Eckert & Malhotra, 2008). Treatment differs depending on the subtype of OSA and patient presentation.

If a patient suffers from obesity, weight loss can lead to improvement in OSA. Treatment for patients with physiologic causes of OSA is more complex and not reliant on behavior modification, instead it may require the interplay of medications, such as oxygen or sedatives, for airway control (Eckert & Malhotra, 2008).

Cluster analysis has determined two main subtypes of patients with obstructive sleep apnea. Group one had high apnea index (AI) and low body mass index (BMI), whereas group two had low AI and high BMI. Group one patients presented with proclined mandibular incisors, retruded mandibles, skeletal open bite tendencies, inferior positioning of the hyoid bone, and large soft palates. Patients with high AI, low BMI, and severe OSA had large anteroposterior skeletal discrepancies and steep mandibular planes.

Group two patients were characterized by soft tissue abnormalities, AI had a high correlation with BMI, and features of these patients were large tongues, soft palates and small upper airways. Group two presentations may be related to obesity, whereas group one presentations may be related to skeletal abnormalities (Tsuchiya et al., 1992).

Three subsets of OSA have also been classified, and coincide with the above grouping (Partinen, Guilleminault, Quera-Salva, & Jamieson, 1988). Three subpopulations were grouped as follows: 1, anatomic abnormalities with an increased mandibular plane to hyoid distance, small posterior airway space width (space behind tongue base to soft tissue) and no obesity, 2, significant obesity and few abnormal cephalometric measurements, and 3, obesity and abnormal anatomy. The group compromised of patients who are obese and have anatomic abnormalities is the largest population of people with OSA. The use of cephalometry is encouraged to help distinguish and determine a patient's correct OSA classification, since approaches to and success of treatment differs for each subtype.

Cephalometry may be a useful tool to help assess OSA patients. The cephalometric radiograph can reveal a depressed position of the hyoid bone (Pracharktam et al., 1996; Partinen et al., 1988; Wong et al., 2005). The hyoid bone may migrate to an anterior and inferior position in OSA to maintain airway patency (Tsuchiya et al., 1992). Increased craniocervical angle measurements can be noted in OSA (Pracharktam et al., 1996; Wong et al., 2005). The craniocervical angle was found to have a strong positive correlation with total airway resistance and turbulent airflow (Wong et al., 2005). This suggests head posture is influenced by the level of airway resistance, as airway becomes restricted a compensatory change in the head postural response may occur to secure an airway.

2.6 The Orthodontist Role

Many orthodontic practices take lateral cephalograms to assess malocclusions of each patient before and after treatment. Tracing cephalometric radiographs is a standard in orthodontic treatment planning and a valuable orthodontic tool. Orthodontists' main focus often involves the examination of five elements: the cranial base, maxilla, mandible, maxillary dentition, and mandibular dentition (Naini, 2011). Although the prediction of growth patterns may arise from the analysis of a patient's lateral cephalometric radiograph, little attention is directed towards the influence of jaw growth and lymphoid tissue on upper airway. A two dimensional image such as the lateral cephalogram comes with limitations in assessing three dimensional anatomy, yet most investigations of the upper airway in orthodontics have remained in this two dimension (Aboudara, Nielsen, Juang, Maki, Miller, & Hatcherf, 2009).

A study that compared lateral cephalograms with cone beam computed tomographic imaging (CBCT) to assess airway concluded that the cephalometric film provided a good overall indicator for nasopharyngeal airway space. The subject with the most constricted airway in two dimension film also presented with the smallest CBCT airway volume (Aboudara et al., 2009). An otorhinolaryngologist can diagnose nasopharyngeal airway obstruction by endoscopy, which has been reported to be an excellent diagnostic tool. A comparison was done to examine the accuracy of nasopharyngeal endoscopy with lateral cephalometric radiography to assess hypertrophy of inferior or middle turbinates, septal deviation, changes in mucous membranes of the meatus, choanae, and adenoids, and to image the soft palate. The lateral cephalometric radiographic image provided limited information when compared with endoscopy, yet it proved to be important in early diagnosis. A lateral cephalographic radiograph is sensitive enough to view hypertrophy of turbinates, the maxillary sinus, and to view changes caudal to the inferior turbinate. Although it is good at identifying hypertrophic soft tissues, caution should be taken due to its reduced accuracy in identifying open spaces when the turbinates are large (Ianni Filho, Raveli, Raveli, Loffredo, & Gandini, 2001). Further, a systematic review analyzed the validity of lateral cephalograms in diagnosing adenoids and restricted posterior nasopharyngeal airways in children and adolescents. The measured adenoid size area on a lateral cephalogram had clinically useful correlations, whereas linear measurements were not as significant. Nasopharyngeal soft tissue area as seen on the radiograph correlated with actual tissue volume that was removed during adenoidectomy. Cephalograms demonstrated to act as an useful initial screening tool for orthodontists, but follow up should be confirmed by thorough testing by an ear-nose-throat doctor (Major, Flores-Mir, Major, 2006).

Similarly, sleep apnea is a condition that frequently may present to the orthodontist. Although it is a multifactorial condition and there are a variety of etiologies, the result is a collapse of upper airway during sleep. An orthodontist should examine suspect patients by thoroughly providing a comprehensive medical history, and sleep history. Cephalometrics can be used to identify the site of obstruction and view the skeletal and dental relationships that may be a causative factor. The airway can be divided into three anatomic sections- the nose, the retropalatal area and the lateral pharyngeal area, and the retroglossal area and the tongue (Jacobson, & Schendel, 2012). Orthodontists should consider nasal aerodynamics and note patient nasal airflow, as maxillary constrictions and crossbites may affect the hard palate/floor of the nasal cavity and lead to deformities. Lymphoid hyperplasia can also be noted by the orthodontist, and reduce the airway space. A patient with a class III malocclusions from a retrusive maxilla may also present with a reduced retropalatal airway. The retroglossal area is highly influenced by tongue position, which may be determined by the patient's mandibular position (Jacobson, & Schendel, 2012). . These three sections should be assessed by a knowledgeable orthodontist. If a child presents with sleep apnea, the orthodontist can play a major role by providing interceptive treatment and improving their skeletal and dental relationships at a young age. Although the primary reason for children to mouthbreath is adenoid or tonsillar hypertrophy, a tonsillectomy or adenoidectomy alone does not resolve airway obstruction in all patients (Jacobson, & Schendel, 2012). It is important to identify all etiologies of obstruction, including skeletal influences. The orthodontist can recognize these anatomic variations in children and adults and become part of a multidisciplinary team to treat them (Jacobson, & Schendel, 2012).

The orthodontist is also responsible for diagnosing a patient's breathing status, identifying if they are a nasal or oral breather. Routine assessment of this by an orthodontist includes visual assessment, medical history, and clinical examination of lip posture, size and shape of nostrils, reflex control of the alar muscle and respiratory tests such as the mirror test (Costa et al., 2017). The orthodontist should observe nasal movement upon breathing, and determine if the dental mirror fogs or has condensation when positioned under the patient's nostrils for 30 seconds. Tonsils can be viewed by use of a tongue depressor. The medical history that is given to patients should include questions of health problems, history of sinusitis or tonsillitis, medications, speech therapy, allergies, breathing issues, stuffy nose, sneezing, snoring, dry mouth upon awakening, suffocation, water drinking during the night, tiredness during the day, nasal spray use, and physical activities. When an orthodontist is suspicious of an airway obstruction, patients should be referred to an otolaryngologist (Costa et al., 2017).

Similarly, the mode in which the patient swallows should be noted during an orthodontist's clinical exam. Swallowing pattern can first be detected while the patient is subconsciously swallowing. The patient can then be instructed to swallow saliva or small amounts of water. Mandibular movement upon swallowing, and any use of perioral muscles can first be observed. The orthodontist may then palpate the temporalis and masseter muscles upon swallowing, or during an unconscious swallow by the patient. This should be done consciously and unconsciously, because the swallowing pattern may differ from normal when it is done on command (Ovsenik, 2009). Normal swallow relies on tooth contact and activation of the muscles of mastication, the perioral and facial muscles should not be active. Tongue thrust swallow does not have the teeth come together to form a seal, instead activation of the perioral muscles dominates this task (Melsen, Attina, Santuari, & Attina, 1987).

A combination of the lateral cephalogram view, along with a clinical exam allows the orthodontist to identify potential airway obstructions in patients. The orthodontist plays a vital role in the initial screening of these patients. A suspicious clinician should perform their preliminary exams, analyze etiologies of each patient's presentation, and may subsequently refer patients to an otolaryngologist for more definitive examination.

CHAPTER 3

AIMS OF THE INVESTIGATION

This study aims to determine the proportion of participating orthodontists whom: 1) Are knowledgeable about airway restrictions and its dental/skeletal etiology, 2) Learned about these topics in post graduate orthodontic education, 3) Consider airway restrictions in orthodontic diagnosis and treatment planning.

Part one aims to determine the proportion of participating orthodontists whom are knowledgeable about etiologies that are associated with and influence airway patency. The questionnaire surveys topics that include tongue position and shape, jaw position and shape, swallowing mechanisms, lymphoid tissue, mouth breathing, and sleep apnea.

Part two aims to determine the proportion of participating orthodontists whom were taught in their orthodontic residency of nasopharyngeal and oropharyngeal airway restrictions, and the proportion of those orthodontists whom received a post graduate curriculum that involved the discussion of tongue position and shape, jaw position and shape, swallowing mechanism variations, lymphoid tissue, mouth breathing, and sleep apnea as comprehensive topics that relate to airway patency.

Part three aims to determine the proportion of participating orthodontists whom diagnose and treatment plan modifications for airway restrictions. It will find the proportion of those that examine tongue position during patient records, those that use lateral cephalograms to identify etiologies of airway narrowing (sleep apnea etiologies or lymphoid tissue), and those whom recommend tonsillectomy/adenoidectomy for patients with enlarged lymphoid tissues.

CHAPTER 4

MATERIALS AND METHODS

4.1 Subjects

Active members of the American Association of Orthodontists (AAO) that practice in the United States are the target population. By utilizing an e-mail list from the AAO, the perspective and practice of orthodontists throughout the country were assessed and included in this study.

4.2 Research Design

A questionnaire was administered through Survey Monkey, an online survey management platform, and sent to the email listings of active AAO members. This survey was sent to the target group by the AAO, with an additional email reminder to complete the survey. After the first round of surveys was emailed, the reminder was sent after fifteen days. Information gathered from the Survey Monkey portal was downloaded into an excel datasheet and analyzed by a computer based software system.

4.3 Questionnaire Description

The questionnaire is divided into three major categories, and asks respondents to answer questions regarding their knowledge of: 1) respiratory function and restrictions, 2) post-graduate residency program education involving respiratory function, and 3) use of this knowledge in diagnosis and treatment planning while in practice. To test respondents' knowledge of respiratory function, included questions assess topics that influence or have a relationship relating to patient respiration. Topics include: tongue position and shape, jaw position and shape, swallowing mechanisms, lymphoid tissue, mouth breathing, and sleep apnea. All survey questions were developed from findings in current literature and have an evidence-based background. The second section of the survey asks if these topics (listed above) were taught in their orthodontic residency curriculum. Lastly, questions assess if and how respondents use their knowledge of airway in diagnosing and treatment planning patient cases. Refer to section 4.5 for the full questionnaire.

4.4 Statistical Analysis

The results gathered from the online survey were analyzed by coding the data and cleaning the data through a computer based software system, SAS 9.3 software. Univariate analyses using proportions, percentages, and frequencies were completed. A Z-proportion test was used for the practice management question (Survey question 34) because this was the only question that summarized the action each orthodontist would take in clinical practice when confronted with a patient that suffers from airway obstruction. Bivariate comparisons of respondents that report they would execute an orthodontic treatment plan for patients that present with restricted airway by using chi-squared test and Fisher's exact test were performed on the collected data.

CHAPTER 5

RESULTS

5.1 Demographics

The survey was distributed to 2,084 AAO members, and received responses from 117 participating orthodontists. The mean age of the sample was 60 years (SD=13 years), with ages ranging from 28-83. The sample of respondents was 78.18% male, and 21.82% female. Their location throughout the United States was almost evenly distributed amongst the Midwest, Northeast, Southeast, and West (26.36%, 22.73, 21.82%, and 20%, respectively), with fewer respondents from the Southwest U.S. (9.09%). The majority of respondents had received their certification from a two year orthodontic program (71.82%).

5.2 Clinician Knowledge

The survey consisted of thirty-five questions that have an evidence based answer. It was constructed into three categories: clinician knowledge, clinician education, and clinician practice. The first section, clinician knowledge, was divided into six topics that are as follows: tongue position and shape (5.2.1), jaw position and shape (5.2.2), swallowing mechanism (5.2.3), lymphoid tissue (5.2.4), mouth breathing (5.2.5), sleep apnea (5.2.6). The results from each question are included within its respective topic heading. In which, a summary of the respondents scores will first be explained, followed by a table inclusive of the true/false questions in that subject with their answers quantified, and a chart of the questions that had descriptive answer responses.

5.2.1 Tongue Position and Shape

The majority of respondents correctly identified tongue adaptations to restricted/obstructed airway.

Table 1. Tongue Position/ Shape: Respondent answers in percentages

Tongue Position/ Shape	TRUE (%)	FALSE (%)	NOT SURE (%)
There are variations in tongue position as a result of oropharyngeal airway restriction	89	3	8
Tongue protrusion may be an adaptation in response to enlarged tonsils or adenoids	88	2	10

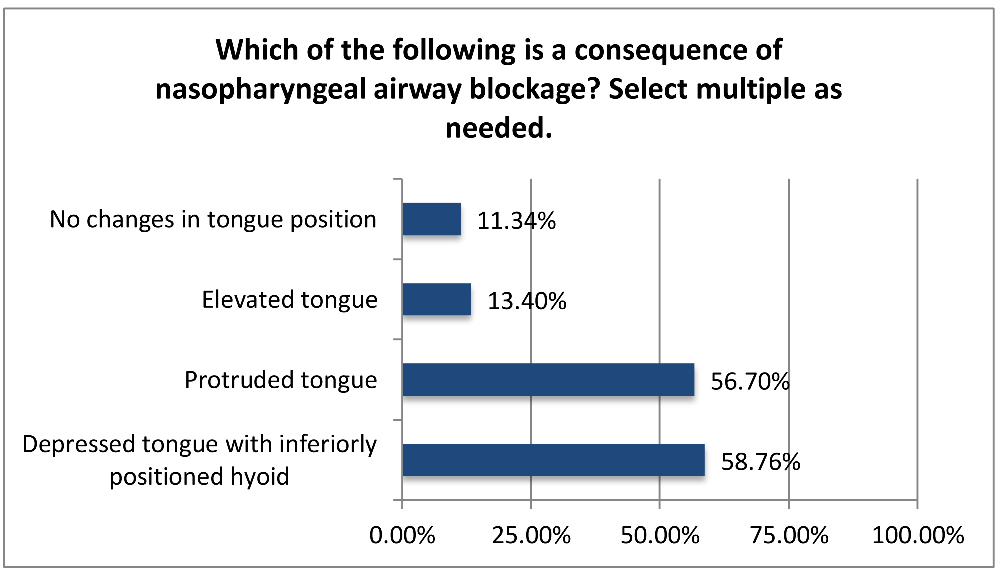

Figure 1. Tongue Position/ Shape: Descriptive Question

5.2.2 Jaw Position and Shape

Responding orthodontists correctly identified that a patient's level of airway resistance influences on head posture. Although respondents were also familiar with the relationship between airway patency and mandibular size and shape, respondents failed to identify that airway volume has a negative correlation with ANB angle. The majority of respondents, 46.46%, were not sure of the relationship between ANB and airway.

Table 2. Jaw Position/ Shape: Respondent answers in percentages

Jaw Position/ Shape	TRUE (%)	FALSE (%)	NOT SURE (%)
The shape and position of the mandible influence changes in respiratory function	85	6	9
Airway volume has a negative correlation with ANB angle	35	18	47
Head posture is influenced by level of airway resistance	76	7	17

5.2.3 Swallowing Mechanism

Respondents were familiar with normal and abnormal swallowing and the mechanisms that allow for such movements, including what muscles are activated during both. Orthodontists also correctly identified facial grimace as a classic sign of abnormal swallowing.

Table 3. Swallowing Mechanism: Respondent answers in percentages

Swallowing Mechanism	TRUE (%)	FALSE (%)	NOT SURE (%)
The muscles of mastication bring the teeth and jaws tightly together during abnormal swallowing	19	55	26
The tip of the tongue is thrust between the teeth during abnormal swallowing	75	12	13
The orbicularis oris, mentalis, and other facial muscles of expression tense during abnormal swallowing	66	8	26

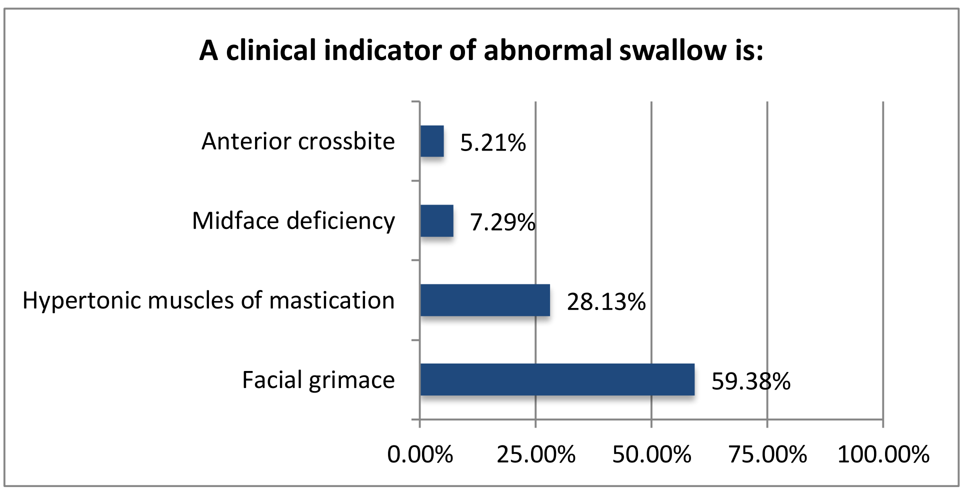

Figure 2. Abnormal Swallow: Descriptive Question

5.2.4 Lymphoid Tissue

Responding orthodontists were knowledgeable about some aspects of the relationship between lymphoid tissue and airway patency, but seemed to be less confident about other aspects. Questions that dealt with habits that were retained after the resolution of enlarged lymphoid tissue, and questions about adenoid facies, were answered correctly by the majority of respondents (79.80% and 82.47%, respectively). 52.53% of respondents knew that a negative correlation existed between patient age and tonsil size. Responses became even less clear when asked about the effects of adenoidectomy and tonsillectomy, with a third of orthodontists reporting the procedures will positively change a person's growth pattern, a third reporting it will not, and a third not sure of the effect.

Table 4. Lymphoid Tissue: Respondent answers in percentages

Lymphoid Tissue	TRUE (%)	FALSE (%)	NOT SURE (%)
Once lymphoid tissue inflammation is resolved, people may retain habits such as tongue protrusion, tongue thrust, or abnormal swallow	80	7	13
Tonsillectomy/adenoidectomy will positively change a person's growth pattern	33	33	33
Negative correlation exists between age of patient and tonsillar size	53	23	24

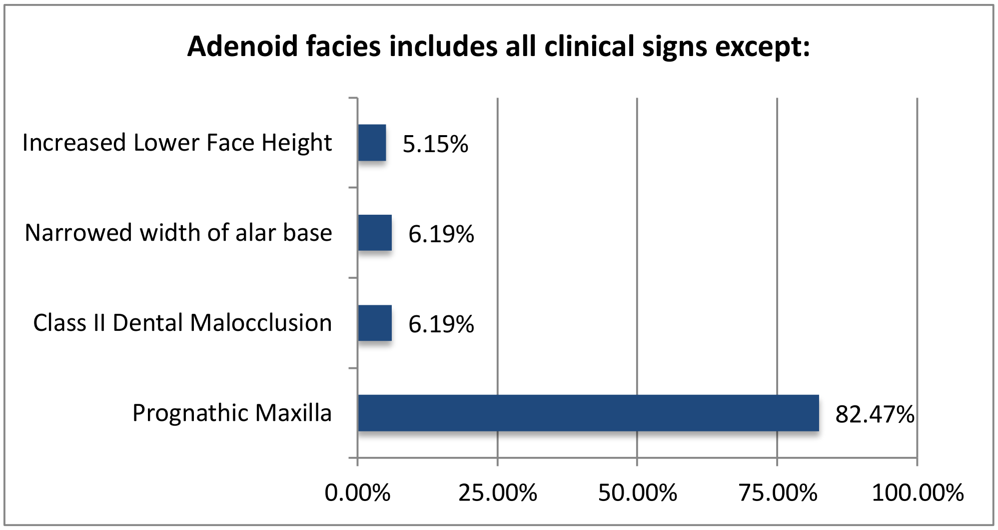

Figure 3. Adenoid Facies: Descriptive Question

5.2.5 Mouth Breathing

Respondents were knowledgeable about the craniofacial changes that are associated with chronic mouth breathing.

Table 5. Mouth Breathing: Respondent answers in percentages

Mouth Breathing	TRUE (%)	FALSE (%)	NOT SURE (%)
Habitual mouth breathing is a definitive sign of restricted airway	37	43	20
Mouth breathing is associated with adenoid facies	72	14	14

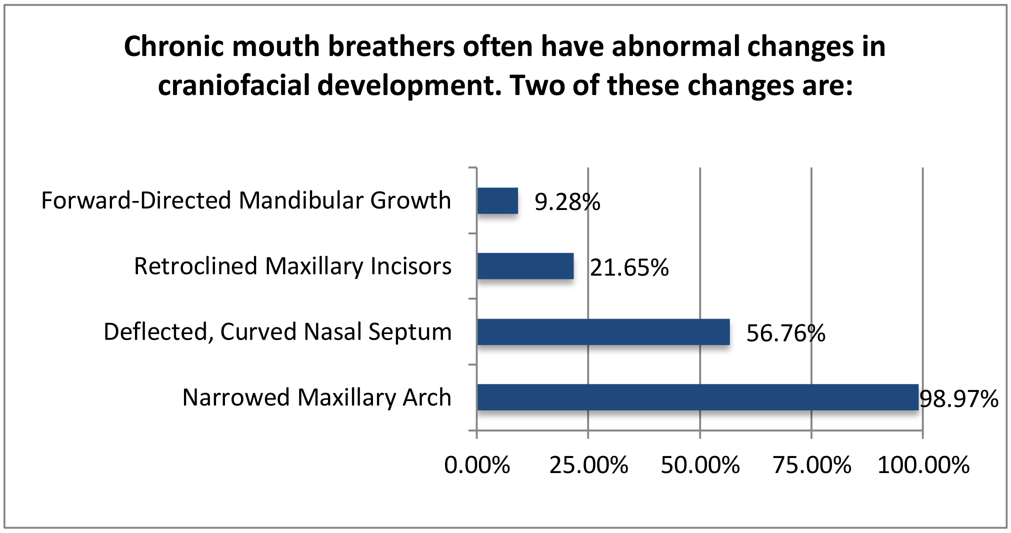

Figure 4. Chronic Mouth Breathing: Descriptive Question

5.2.6 Sleep Apnea

Responding orthodontists were familiar with different presentations of sleep apnea, and recognize that a person may have a high apnea index with low body mass index, or may have ideal occlusion yet still are affected. The majority of respondents, 66.33%, also correctly related mandibular deficiency with sleep apnea.

Table 6. Sleep Apnea: Respondent answers in percentages

Sleep Apnea	**TRUE (%)**	**FALSE (%)**	**NOT SURE (%)**
Sleep apnea patients may have a high apnea index but present with low body mass index	72	16	12
Sleep apnea does not occur in young adult patients who have ideal occlusion after the completion of orthodontic treatment	3	86	11

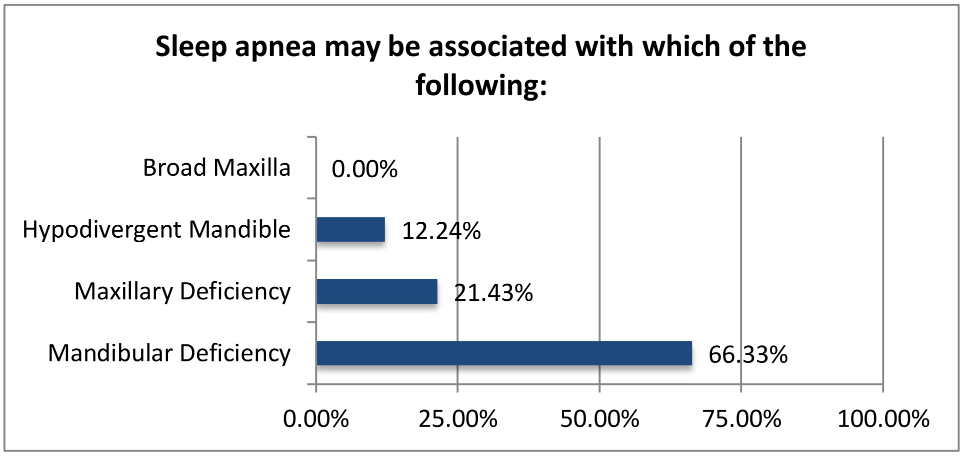

Figure 5. Sleep Apnea: Descriptive Question

5.3 Clinician Education

50.51% of respondents were taught about restricted or obstructed oropharyngeal and nasopharyngeal airway in their post-graduate orthodontic education. 40.4% of respondents were not taught this topic, and 9.09% were not sure if this was taught. Most respondents were taught that lymphoid tissue, and mouth breathing were etiologies/influencers of restricted airway, with the least amount of respondents being taught of the association of restricted airway and sleep apnea.

The chart below represents topics taught that impact restricted airway:

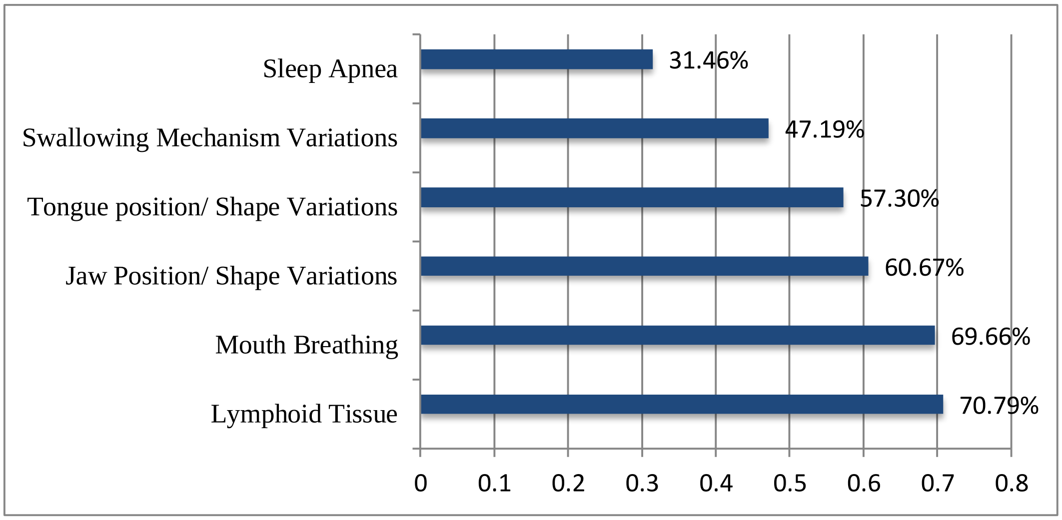

Figure 6. Airway Education Topics: Descriptive Question

5.4 Clinician Practice

The majority of survey respondents (77.32%) examine tongue position during routine exam, by clinical examination only (44.57%), or by both clinical and radiographic examination (36.96%). 22.68% of respondents do not note tongue position in their patient examination.

Respondents also refer to the lateral cephalogram for additional information when analyzing a patient's airway. This radiograph is most used in sleep apnea to identify restrictions in airway size (42.27%), determine mandibular position relative to cranial base (41.24%), and assess size of lymphoid tissue (35.05%).

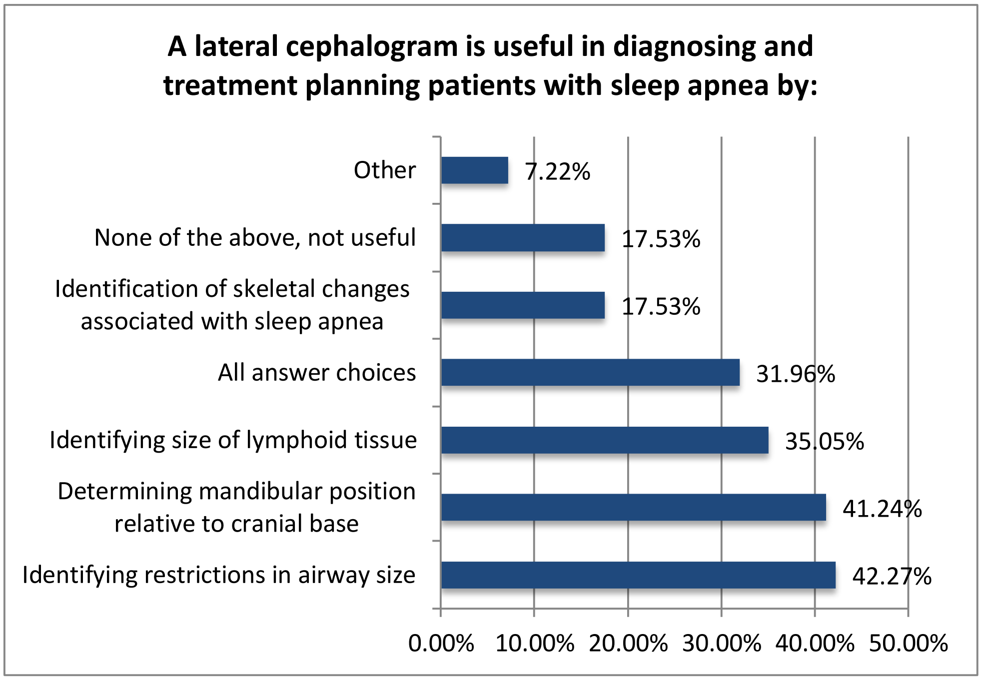

Figure 7. Lateral Cephalogram Use: Descriptive Question

When asked if size of adenoids as portrayed on a lateral cephalogram is useful in identifying nasopharyngeal airway obstruction, almost 2/3 (61.46%) of respondents thought it had value. Respondents' views on adenoidectomy and tonsillectomy indications were slightly less clear. Respondents reported that if their patient had obstructed airway due to adenoid or tonsillar enlargement, 58.33% believed their patient should undergo adenoidectomy or tonsillectomy, whereas 36.46% were not sure if this surgical procedure was indicated. 5.21% of respondents did not think their patient should undergo these procedures, even if they presented with enlarged lymphoid tissue.

An airway issue may present in many ways, with indicators in clinical exam and radiographic exam. The participating orthodontists reported that most often, this diagnosis comes from the patient self reporting (79.17%). Additionally, 73.96% of orthodontists identify restricted/obstructed airway by clinical examination. Medical and/or dental history records were used by 69.79% of clinicians, and radiographic exam by 58.33%. According to the results of this survey, radiographic information is least useful in identifying airway restrictions.

The majority of clinicians, 66.32%, reported that they refer for medical consultation to the appropriate clinician before they begin treatment if a patient presents with restricted airway and is interested in comprehensive orthodontic treatment. 26.32% of respondents would treat this patient as normal but monitor airway as part of a therapeutic diagnosis for treatment. A minority of clinicians would not treat until airway impairment is resolved (1.05%), or would execute treatment plan without modifications (6.32%).

To understand how an orthodontist with a specific background (gender, program length, previous education in the subject or related topics) may act clinically when a patient presents with restricted airway, the orthodontist's survey responses were stratified against survey question 14. Survey question 14 asked "How do you manage a patient who presents with a restricted airway when treatment planning him/her for comprehensive orthodontics," with answer choices, "1. Execute treatment plan without modification, 2. Refer for medical consultation to appropriate physician before begin treatment, 3. Treat as normal but monitor restricted airway as part of therapeutic diagnosis for treatment, 4. Not treat until airway impairment is resolved." Survey respondents were asked to select one answer.

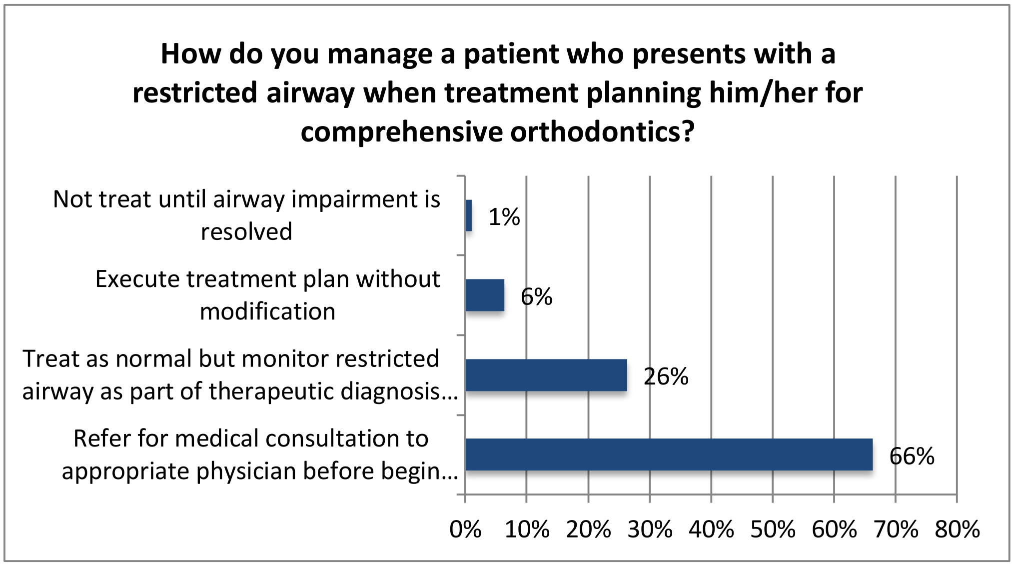

Figure 8. Practice Management: Descriptive Question

66% of respondents would refer for medical consultation to the appropriate physician, 27% would treat as normal but monitor, 6% would execute treatment plan without modification, and 1% would not treat until airway impairment is resolved. The groups show statistically significant differences between one another, with $p < 0.00001$.

The groups included above that would execute treatment with or without monitoring airway were combined, and bivariate analyses were run to determine if gender, program length, or education influenced the orthodontists' clinical decision. The table below compiles this data.

Table 7. Bivariate Comparison of Executing Orthodontic Treatment

Bivariate comparisons of respondents that report they would execute an orthodontic treatment plan for patients that present with restricted airway:					
Variable (Group 1 / Group 2)	**Group 1 %**	**Group 2 %**	**Odds Ratio**	**95% CI**	**P - Value**
Gender (Male / Female)	35.9	29.41	1.34	0.43-4.21	0.61
Program Length (>2yrs / 2yrs)	26.9	36.2	0.65	0.26-1.76	0.39
Taught about airway in orthodontic education (Yes / No)	34.69	34.04	1.03	0.44-2.39	0.94
Taught tongue position/shape variation (Yes / No)	34	34.78	0.97	0.42-2.24	0.94
Taught jaw position/shape variation (Yes / No)	39.62	27.91	1.7	0.71-4.02	0.23
Taught swallowing mechanism variations (Yes / No)	39.02	30.91	1.43	0.61-3.34	0.41
Taught lymphoid tissue (Yes / No)	32.79	37.14	0.83	0.35-1.97	0.67
Taught mouth breathing (Yes / No)	39.34	25.71	1.87	0.75-4.68	0.17
Taught sleep apnea (Yes / No)	26.92	37.14	0.62	0.23-1.68	0.35

CHAPTER 6

DISCUSSION

The survey yielded responses from throughout the United States and was approximately evenly distributed throughout the Midwest, Northeast, Southeast and West. Although fewer respondents were from the Southwest, the diversity in respondent location allows results to be applied to the broader population. Further, the age of respondents varied from 28-83 years, with a mean age of 60 years. The age range is important to note, as the emphasis on airway knowledge and education has varied over the years and may be more of a priority in current orthodontics than it has been in the past.

Only 50% of respondents were taught of restricted or obstructed airway in their post-graduate education. This identified a large void in the involved orthodontic population, with half of respondents not taught, or not sure they were taught, of this topic. A problem is obvious, this topic is lacking in post-graduate orthodontic curriculum. A lack in standardization of topics is clear; residents are not being educated on this topic and do not have a knowledge base of restricted airway to apply to clinical practice. Those that had been taught of this general topic during orthodontic education had learned about all different aspects and etiologies associated with airway. Most common topics taught were lymphoid tissue (71%), mouth breathing (69.66%), and jaw position/shape variations (61%), whereas sleep apnea was the least commonly taught (31%). There is no standardization in these topics. If a standard base curriculum in relation to this topic was required in residency, a more balanced and complete education would exist and benefit orthodontists nationwide.

In general, it was somewhat reassuring that respondents had correct knowledge on the majority of topics included in the survey, and were familiar with tongue adaptations to restricted airway, craniofacial changes associated with chronic mouth breathing, sleep apnea, differing swallowing mechanisms, airway patency in relation to mandibular size and shape, and some aspects of lymphoid tissue's influence on airway. Almost 90% of respondents knew that there are variations in tongue position as a result of oropharyngeal airway restriction. Similarly, 88% of respondents knew that tongue protrusion may be an adaptation in response to enlarged tonsils or adenoids. Respondents also correctly stated that a depressed tongue with inferiorly positioned hyoid may be found, in addition to tongue protrusion, in airway blockage. The relationship between the tongue and airway patency seems to be known to this population. It is more concerning that a subset of respondents were not able to properly answer multiple questions, spanning different topics, that relate to airway knowledge. 10% of responding orthodontists did not know or were not sure that there are variations in tongue position as an adaptation to airway restriction, and 10% of respondents were not sure if the tongue would protrude in response to enlarged lymphoid tissue. The lack of generalized understanding is clear throughout the survey responses. This will be further detailed below.

A reduced airway patency may also result in chronic mouth breathing; mouth breathing requires less work than nasal breathing with an airway obstruction (Proffit et al., 2007). According to Oliver (1918), a patient immediately becomes a mouth breather when the adenoids/tonsils are large enough to restrict airway. The effects of chronic mouth breathing on development are important for an orthodontist to recognize. Respondents generally identified craniofacial changes that result from chronic mouth breathing, such as a narrowed maxillary arch, and deflected, curved nasal septum. With mouth breathing, the mouth is primarily open, and the tongue remains in an inferior position, it does not have the ability to exert lateral force on the developing maxilla. These patients also experience changes in atmospheric pressure, and reduced downward growth of the maxilla, resulting in less room for the nasal septum to properly elongate (Baker, 1954). Although 72% of respondents knew mouth breathing was associated with adenoid facies, 14% of respondents were not sure of the association, and 14% believed there was no association. The specific identifying features of adenoid facies has been well documented and described, with the most common clinical signs of narrow alar base and face, increased lower face height, narrow maxillary arch, dental posterior crossbites, and class II dental malocclusion (Basheer et al., 2014). It is shocking that this general association is not known by 28% of respondents. This poses a problem in clinical practice; many patients that may suffer from mouth breathing and other airway pathologies are not being recognized by the specialist. Further, respondents were not sure if “Habitual mouth breathing is a definitive sign of restricted airway;” 37% responded this statement was true, 43% false, and 20% not sure. Habitual mouth breathing is not a definitive sign, but should be an indicator for more thorough examination. Mouth breathing is a convenient way to secure an airway when problems with nasal airflow exist, and should be noted by the orthodontist as a clinical sign of an underlying problem.

It is clear from the results of the questionnaire that a large subset of orthodontists nationwide are not educated in or do not understand these topics and therefore are not able to provide holistic care for their patients.

Survey questions regarding sleep apnea were accurately answered by the majority of the responding orthodontists, but a decent percent of orthodontists did not select correct answers. Often, people think of the stereotypic patient who suffers from sleep apnea as an adult male with high body mass index. The main risk factor for sleep apnea is obesity, and there is an increased risk in males, and older individuals (>65 years) (Eckert & Malhotra, 2008). It is important for orthodontists to recognize that there are other predisposers for this condition and understand the diversification of those that can be affected by sleep apnea. 16% of responding orthodontists did not think sleep apnea patients may have high apnea index but low body mass, 12% were not sure. The different presentations of sleep apnea need to be better recognized and understood. Tsuchiya et al. (1992) investigated subtypes of patients of sleep apnea, and recognized a group of affected patients with skeletal and muscular abnormalities such as mandibular deficiency, inferior hyoid positioning, large soft palate, skeletal open bite, and proclined mandibular incisors. Survey questions asked about the less typical presentations of sleep apnea. 72% of respondents recognize that sleep apnea patients may have a high apnea index but present with low body mass, and 86% knew that it could occur in young adult patients with ideal occlusion after the completion of orthodontic treatment. Although a majority, only 66% of respondents correctly identified mandibular deficiency as a feature that may be associated with sleep apnea.

Swallowing is also another individualized motion that should be recognized upon patient evaluation by the orthodontist. The normal swallowing mechanism involves a sealing of the oral cavity from the teeth and jaws coming together by activation of the muscles of mastication (Straub, 1960). Facial expression muscles aid in creating a seal when an abnormal swallowing mechanism takes place. Orthodontists were asked about the muscles that help swallowing occur; only 55% of respondents knew that muscles of mastication do not bring the teeth and jaws together in abnormal swallow, while 65% knew that facial muscles of expression instead tense in abnormal swallow. A higher percentage of orthodontists, 75%, were confident that the tip of the tongue is placed between the teeth during abnormal swallow. It seems that the intricacies of these modalities may not be understood by the respondents.

It is interesting that although respondents correctly answered that the shape and position of the mandible influence changes in respiratory function, and that head posture is influenced by level of airway resistance, they failed to identify that airway volume has a negative correlation with ANB angle. As the ANB angle increases, as it does a worsening Class II skeletal malocclusion, the airway volume decreases. It is peculiar that respondents acknowledged the relationship of the mandible with airway, but not of ANB with airway. The majority of respondents, 46.46%, were not sure of the relationship between ANB and airway.

Lymphoid tissue was another topic from the survey in which respondents did not accurately answer all questions. When asked about clinical signs of adenoid facies, and about over retained habits after the resolution of enlarged lymphoid tissue, the respondents were in agreement and were knowledgeable about each answer. Responses became less clear when orthodontists were further asked about lymphoid tissue. Only 52.53% of respondents knew that a negative correlation existed between patient age and tonsil size. As Scammon (1930) demonstrated in the growth curve, lymphoid tissue size is about 200% greater in a child 11-13 years old, than that found in an adult. When asked about the effects of adenoidectomy and tonsillectomy, a third of orthodontists reported the procedures will positively change a person's growth pattern, a third reported it will not, and a third were not sure of the effect. There was equal confusion evident in the practice section when respondents were asked if a patient that has enlarged adenoids or tonsils should undergo adenoidectomy or tonsillectomy. 58.33% of respondents answered "yes," and 36.47% were "not sure." With these differing responses, it is of utmost importance to see the clinical implications, be able to recognize a problem, and for orthodontists to refer patients to an otolaryngologist for further evaluation.

Although an orthodontist does not diagnose sleep apnea or other airway restrictions, they may be the first professional to assess any problem and subsequently refer. Indicators of airway obstruction may arise from the records taken during a patient's initial exam. A lateral cephalogram can be useful to identify multiple indicators of breathing problems. Respondents believed this radiograph was most useful to help identify restrictions in airway size (42.27%), and to determine mandibular position relative to the cranial base (41.24%). Both of these factors may limit airway patency. A lateral cephalogram may also be used to help identify skeletal changes associated with sleep apnea. Respondents had the opportunity to disclose their own reasons for reviewing the lateral cephalometric radiograph in the “other” section, which included: position of the hyoid bone and tongue position at rest, and that it gives a two dimensional view of airway which may suggest further imagining. As noted by Tsuchiya (1992), the hyoid bone may migrate to an inferior position in patients’ with sleep apnea as a way to maintain airway patency. Respondents did not mention that the lateral cephalometric radiograph may also be useful to determine the craniocervical angle, which has a strong correlation with airway resistance and turbulent airflow (Wong et al., 2005). Some respondents said they use cone-beam computed tomography instead of a lateral cephalogram to produce their records and analyze airway. 17.53% of respondents report that the lateral cephalometric radiograph is not useful for analysis of patients with sleep apnea. This sector of orthodontists may benefit from a more thorough orthodontic curriculum, or continuing education that relates to sleep apnea, and/or radiology, with an emphasis on patient features that can readily be identifiable in a radiograph.

When the responding orthodontists were asked, “How do you manage a patient who presents with a restricted airway when treatment planning for comprehensive orthodontics,” a low majority of respondents (66.32%) stated that they would “refer for medical consultation to appropriate physician before begin treatment.” It is generally recommended to become part of a multidisciplinary team (Jacobson, & Schendel, 2012) and refer a patient with an airway obstruction to the appropriate physician, that often being an otolaryngologist (Major et al., 2006; Costa et al., 2017). The differences amongst respondent answer choices for this question were statistically significant ($p < 0.00001$). 33.68% did not think the first step would be to refer; 26.32% would “treat as normal but monitor restricted airway as part of therapeutic diagnosis for treatment," 6.32% would "execute treatment plan without modification," while 1.05% would not treat until airway impairment is resolved. These statistically significant differences in clinical practice highlight the lack of standardization found amongst practitioners throughout the United States. A patient may receive very different modalities of care depending on which practitioner they visit. A step should be made within the orthodontic community to create general guidelines for management of these patients and allow for equal care to all patients.

The survey responses were analyzed further to investigate if there were trends in the type of person that would treat this patient instead of first referring to a physician. The "treat as normal but monitor" and "execute treatment plan" groups were combined, which results in 32.64% of respondents stating they would treat the airway obstructed patient. No statistically significant differences were found amongst any group that selected this response. Gender did not seem to greatly influence if the clinician would treat the airway obstructed patient; males (35.9%) were slightly more likely to treat this patient than females (29.41%). Orthodontists that attended a two year program (36.2%) were more likely to treat than those that attended a program longer than two years (26.9%). This trend may imply that a longer program has more time to teach these topics, but this has yet been proven. In terms of restricted airway being taught during post graduate education, it does not seem to make a difference if the general topic was taught (34.69%) or not taught during residency (34.04%), with similar percentages answering that they would treat the patient. The data from this sample of respondents suggests that education in certain topics does not make a difference in the orthodontists' decision to refer or immediately treat.

When specifically asked about the topics taught, the most differences were seen in the groups that were or were not taught of jaw position/shape variation, and those that were or were not taught of sleep apnea. 39.62% of respondents that were taught about jaw position and shape variations in relation to airway obstruction would execute orthodontic treatment when a patient presents with an airway issue, whereas 27.91% of those not taught this topic would treat. This is interesting because it would be assumed that the more informed the orthodontist is and topics that one is a master in, the more likely the orthodontist would be to refer. Instead, those respondents that were not educated in this topic seemed to refer more (would execute treatment less). This may be due to a lack of knowledge about any protocol, and the orthodontist may be more likely to refer to get a second opinion by a more knowledgeable professional.

26.92% of those that would treat patients with airway restrictions were taught of sleep apnea, whereas 37.14% were not taught this topic in residency. This topic shows an opposite trend when compared to jaw position/shape education. A higher percentage of those that were not educated in sleep apnea would execute the treatment plan versus those educated in this. This leads to speculation that some orthodontists whom were not taught of sleep apnea may not have the skill to identify, or know the importance of recognizing and resolving an airway issue.

Overall, the low majority of respondents would not execute treatment right away. It seems that regardless of topics taught during post graduate orthodontic education, program length, or gender, the trend is to refer identified patients to the appropriate physician. Moving forward in the orthodontic profession, more doctors need to be able to recognize these interconnected pathologies, identify patient adaptations and variations in presentation, and understand the importance of referring to a physician.

CHAPTER 7

CONCLUSIONS

1. The majority of survey respondents were knowledgeable about the relationship of tongue shape/position, swallowing mechanism, breathing pattern, and sleep apnea, with airway patency. These orthodontists were able to correctly answer the majority of questions relating to these topics, implying that they are educated in the subject.

2. The survey identified that respondents showed variation in responses when asked questions regarding jaw shape/position, and lymphoid tissue in relation to airway patency. There is a lack in understanding of this relationship demonstrated by the inconsistency in selected survey answers.

3. Only 50.51% of respondents were taught about restricted airway in their post graduate orthodontic education. Lymphoid tissue and mouth breathing were the most commonly taught topics in residency. Sleep apnea, followed by swallowing mechanism variations, were the topics that were taught least in residency. Further emphasis should be placed on these topics in the orthodontic residency curriculum and in continuing education to help practitioners expand knowledge and improve patient care.

4. Management of patients with airway obstruction varies amongst practitioners. There are statistically significant differences ($p < 0.00001$) in how respondents would manage a patient that has an airway abnormality but presents for orthodontic care. This finding shows that there is great variation in orthodontic practices throughout the United States. When presented with a patient that has an airway restriction, a low majority of respondents stated that they would refer the patient for medical consult before orthodontic treatment commences. It is clear that there is not a known standard in current clinical practice in identification method or screening of airway patency and one is needed.

5. Orthodontics nationwide would benefit from more thorough post graduate orthodontic residency curriculum and general guidelines for clinical management of patients that present with airway obstruction.

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APPENDIX

Airway Questionnaire

Respondent Demographics:

1. What is your age (please write number)?
2. What is your gender? M / F
3. Where are you located? Northeast, Southeast, Midwest, West, Southwest
4. In which year did you complete your orthodontic training?
5. Length of the program? Two year / Three year

<u>Part I.</u> The following section discusses etiologies of restricted airway:
(Correct answers bolded)

6. There are variations in tongue position as a result of oropharyngeal airway restriction.

a. True
b. False
c. Not sure

7. The shape and position of the mandible influence changes in respiratory function.

a. True
b. False
c. Not sure

8. Airway volume has a negative correlation with ANB angle.

a. True
b. False
c. Not sure

9. Sleep apnea patients may have high apnea index but present with low body mass index.

a. True
b. False
c. Not sure

10. Sleep apnea does not occur in young adult patients who have ideal occlusion after the completions of orthodontic treatment.

a. True
b. False

c. Not sure

11. Head posture is influenced by level of airway resistance.
    a. True
    b. False
    c. Not sure

12. Habitual mouth breathing is a definitive sign of restricted airway.
    a. True
    b. False
    c. Not sure

13. Mouth breathing is associated with adenoid facies.
    a. True
    b. False
    c. Not sure

14. Tongue protrusion may be an adaption in response to enlarged tonsils or adenoids.
    a. True
    b. False
    c. Not sure

15. Once lymphoid tissue inflammation is resolved, people may retain habits such as tongue protrusion, tongue thrust, or abnormal swallow.
    a. True
    b. False
    c. Not sure

16. Tonsillectomy/adenoidectomy will positively change a patient's growth pattern.
    a. True
    b. False
    c. Not sure

17. Negative correlation exists between age of patient and tonsillar size.
    a. True
    b. False
    c. Not sure

18. The muscles of mastication bring the teeth and jaws tightly together during abnormal swallowing.
    a. True
    b. False

c. Not sure

19. The tip of the tongue is thrust between the teeth during abnormal swallowing.

a. True
b. False
c. Not sure

20. The orbicularis oris, mentalis, and other facial muscles of expression tense during abnormal swallowing.

a. True
b. False
c. Not sure

21. Which of the following is a consequence of nasopharyngeal airway blockage? Select multiple as needed.

a. Protruded tongue
b. Elevated tongue
c. Depressed tongue with inferiorly positioned hyoid bone
d. No changes in tongue position

22. Sleep apnea may be associated with which of the following:

a. Maxillary deficiency
b. Mandibular deficiency
c. Hypodivergent mandible
d. Broad maxilla

23. Chronic mouth breathers often have abnormal changes in craniofacial development. Two of these changes are:

a. Narrowed maxillary arch
b. Deflected, curved nasal septum
c. Retroclined maxillary incisors
d. Forward- directed mandibular growth

24. Adenoid facies includes all clinical signs except:

a. Prognathic maxilla
b. Class II dental malocclusion
c. Narrowed width of alar base
d. Increased lower facial height

25. Adenoid facies is caused by:

a. Adenoid enlargement; other lymphoid tissue is normal size
b. Tonsillar enlargement; other lymphoid tissue is normal size
c. Both adenoid and tonsillar enlargement
d. Neither adenoid or tonsillar enlargement

e. A, B, C

26. A clinical indicator of abnormal swallow is:
   - a. Midface deficiency
   - b. Hypertonic muscles of mastication
   - c. Anterior crossbite
   - **d. Facial grimace**

Part II. ***The following section discusses post- graduate orthodontic residency educational experience:***

27. Restricted or obstructed oropharyngeal and nasopharyngeal airway was a topic taught in your post-graduate orthodontic education.
   - a. Yes
   - b. No
   - c. Not sure

28. Which topics listed below, if any, were taught as etiologies or influencers of restricted airway in your post-graduate orthodontic education? Select all that apply.
   - a. Tongue position/ shape variation
   - b. Jaw position/ shape variations
   - c. Swallowing mechanism variations
   - d. Lymphoid tissue
   - e. Mouth breathing
   - f. Sleep apnea

Part III. ***The following section discusses management of restricted airway in practice:***

29. Do you examine tongue position during routine exam?
   - a. Yes
   - b. No

30. If yes, then how?
   - a. Clinical only
   - b. Radiographic only
   - c. Clinical and radiographic exams
   - d. Neither, do not note tongue position

31. How is a lateral cephalometric radiograph useful in your diagnosing and treatment planning of patients with sleep apnea?
   - a. Identification of skeletal changes associated with sleep apnea
   - b. Identifying restrictions in airway size
   - c. Identifying size of lymphoid tissue

d. Determining mandibular position relative to cranial base
e. All of the above
f. None of the above, not useful

32. How do you diagnose restricted/obstructed airway in your clinical practice? Select all that apply.
a. Patient self report
b. Medical and/or dental history records
c. Clinical exam
d. Radiographic exam

33. Do you think the size/appearance of adenoids on a lateral cephalogram is useful in diagnosing nasopharyngeal airway obstruction?
a. Yes
b. No

34. A patient that is treatment planned for comprehensive orthodontics, who also has a restricted airway, do you:
a. Execute treatment plan without modification
b. Refer for medical consultation to appropriate physician before begin treatment
c. Treat as normal but monitor restricted airway as part of therapeutic diagnosis for treatment
d. Not treat until airway impairment is resolved

35. A patient that is treatment planned for comprehensive orthodontics, who also has an obstructed airway due to enlarged tonsils or adenoids, should undergo tonsillectomy/adenoidectomy.
a. True
b. False
c. Not sure