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Correlation between dental classification and upper airway measurements using acoustic rhinometry and pharyngometry

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THESIS

CORRELATION BETWEEN DENTAL CLASSIFICATION AND UPPER AIRWAY MEASUREMENTS USING ACOUSTIC RHINOMETRY AND PHARYNGOMETRY

by

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DEDICATION

I would like to dedicate this work to my mother and father who enabled me the opportunity of pursuing a further education in the United States.

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Boston University, Henry M. Goldman School of Dental Medicine, 2018

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ABSTRACT

Purpose: To determine the prevalence of Sleep Disturbances (SD) in children and to evaluate the correlation between dental classification and airway dimensions. **Methods:** Children between 3 – 18 years at the Boston University Pediatric Oral Healthcare Center in Boston, Massachusetts were recruited for this study. Based on parents' responses in a brief sleep-screening questionnaire, cases were identified as children with SD and controls were those without. Another detailed questionnaire was used to collect information on demographics and sleep patterns. Clinical and upper airway examinations were conducted using Eccovision Acoustic Rhinometer (AR) and Acoustic Pharyngometer (AP). Statistical differences in upper airway measurements by type of dental occlusion were evaluated. **Results:** Among 281 children, the prevalence of SD was 38%. Upper airway measurements among 176 participants using AP showed significantly higher pharyngeal Minimum Cross-Sectional Area (MCA) for class III dental occlusion compared to class I (P=.036) in children with SD. Statistically significant differences in MCA, Airway Volume (AV), and minimum distance to MCA by type of dental occlusion were mainly observed among children with SD ($P<.05$). **Conclusions:** The results highlight a possible correlation between nasal and pharyngeal airway dimensions and dental classification among children with SD. Further analysis that include radiological examinations may help in confirming these findings.

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INTRODUCTION

Sleep disturbances (SD) are a relatively common condition affecting both children and adults.[1,2] In the United States, approximately 50% of the adolescents between the ages of 15 to 17 years and more than 33% of children ranging from 6 to 8 years are reported to have sleep problems at least one day per week.[3] One of the possible causes of SD is sleep-disordered breathing (SDB).[4] The clinical presentations of SDB include upper airway resistance syndrome, obstructive sleep apnea (OSA), and snoring.[4] Some studies show a possible correlation between SD and upper airway size, and several others relate differences in upper airway size by type of skeletal classification.[3,5] Nasal and airway dimensions can easily be determined by the use of diagnostic methods such as lateral cephalometric radiographs, computed tomography, magnetic resonance imaging, and acoustics.[6,7,8,9] Acoustic Pharyngometry (AP) is a newer method that employs the use of sound reflection to estimate the upper pharyngeal cross-sectional area as a function of the distance between the airway and the oral opening.[10] Acoustic Rhinometry (AR) is similar to AP and is an objective method that can be used to examine the patency of the nasal cavity.[9] Both techniques are reliable, rapid, non-invasive, and have shown remarkable reproducibility during in vivo and clinical measurements.[11,12] They are preferred methods for the pediatric population since they require minimal co-operation from the subject.[9]

In the assessment of pharyngeal airway dimensions in children with varying skeletal patterns, those with mandibular deficiency are found to have lower airway volume, area, and pharyngeal airway space than those with a good anteroposterior relationship.[5]

While the majority of studies have focused on the relationship between skeletal classification and airway size, few have evaluated the relationship between dental classification and airway size. In studies that explored the relationship between airway size and Angle's dental classification, the results were inconclusive especially among children.[13,14] The evidence was however based on limited data and thus necessitates further investigation, which lead to the reason for this study.

The purpose of this study was to determine the prevalence of sleep disturbances in children 3-18 years and to evaluate the correlation between dental classification and airway dimensions using acoustic diagnostic methods, AR and AP. Evaluating dental occlusion is effective in cases where lateral cephalometric radiographs are not taken. Should a correlation between dental classification and upper airway dimensions be made, early and effective treatment approaches may be considered.

METHODS

Boston University Medical Center (BUMC) Institutional Review Board (IRB) approved this study. An outline of the study methods is illustrated in Figure 1. This study was conducted at the Boston University Henry M. Goldman School of Dental Medicine's Pediatric Oral Healthcare Center (POHC) and Boston Medical Center's Department of Pediatric Dentistry in Boston, Massachusetts. During routine dental visits, parents or guardians of children seen at BMC and the POHC completed a short sleep-screening questionnaire, the BEARS algorithm, as part of routine screening and recording of complete medical and dental history (Appendix 1). The BEARS algorithm is a simple, cost-effective and validated sleep screening questionnaire that is helpful in assessing SD and estimates five major sleep domains which are: B (Bedtime problems), E (Excessive daytime sleepiness), A (Awakenings during the night), R (Regularity and duration of sleep) and S (Snoring).[15,16] This screening tool was originally formulated to aid in the identification of children with SD and those without the problem.[15] A positive response to any of the questions on sleep behavior affirmed the patient as a case subject, whereas negative answers to all questions determined the participant as a control subject. Once this initial screening was completed, parents or guardians of children aged 3-18 years were informed about this research study and those who were willing for their children to be a part of this research study completed the formal consent process.

After obtaining written informed consent, parents or guardians of children identified as either a case or a control completed a more detailed study questionnaire which included selected questions from the validated Pediatric Sleep Questionnaire (PSQ, Appendix 2). The detailed study questionnaire obtained information on complete health history, demographics, current intake of medications, if any, wake-time behaviors, and children's nocturnal habits. They were also scheduled for a second follow-up appointment to complete a comprehensive clinical examination. The clinical examination comprised of an extra oral examination, an intraoral examination as well as nasal and pharyngeal airway measurements using AP and AR. The extra oral examination was made up of assessments of facial divergence pattern, observed breathing pattern (nose vs. mouth) and facial profile. The intraoral exam entailed a detailed assessment of the bilateral molar dental classification (or canine classification if the molars were absent), and an evaluation of maxillary arch width, taking into account any crossbites.

Rhinometry and pharyngometry measurements were done with the use of an Eccovision Acoustic Diagnostic Pharyngometer (Hood Laboratories, Pembroke, MA; Figure 4). This device employs a patented, state-of-the-art acoustic signal processing technology to provide a graphical representation of upper airway patency. The technique is non-invasive and results are available in real-time. The patients sat in an upright position in an armchair while maintaining their head at a proper position and breathed normally. A separate nosepiece was fit smoothly into the nasal and oral cavity. A sound signal was then allowed to travel through the airway and reflected back. The system was able to capture the sound reflection with ease. The results of the upper airway evaluation are shown as a graph on the display device. The pharyngeal analysis segment (AS) in Figure 2 demonstrates a graph of the cross-sectional area of the oral cavity (Y-axis) against the distance into the oral cavity (X-axis), with the opening of the mouth for airway dimensions. The minimum cross-sectional area (MCA) is the narrowest part of the nasal or pharyngeal airway, and is measured in $cm^{2.}$ Pharyngeal airway volume (AV) represents the volume of the area between the oropharyngeal junction to the glottis, measured in cc.[(17)] Minimum distance (MD) is the position at which the MCA occurred; units are in cm. Pharyngometry measurements were repeated four times to ensure accuracy.

Figure 3 depicts a sample rhinometry analysis segment. Each graph corresponds to either the right or left nostril. Similar to pharyngometry analysis segment, this graph is a function of the nasal cross-sectional area as a function of the distance from the nose piece (at 0.0cm). In this acoustic device, rhinometry volume is defined as the volume of the nasal airway from each nostril to the nasopharyngeal region, measured in cc units. Rhinometry minimum cross-sectional area (MCA) is the minimum area detected in the analysis segment (AS), measured in cm^2. Air resistance (ARe) is calculated as the resistance of an equivalent duct segment which possesses similar cross-sectional area, with the assumption that the shape is circular.

Data analysis was conducted using STATA statistical software version 14.0. Two-sample T-tests and Pearson chi-square tests were used to evaluate significant differences in demographic parameters among children with SD (cases) and those without (controls). Analysis of variance (ANOVA) was used to evaluate differences in upper airway measurements between dental occlusion types among cases and controls. Kruskal-Wallis tests were conducted for non-normal data. A *P*-value of $<.05$ was considered statistically significant. Multivariate analyses were done using linear regression models for both AP and AR measurements. Values were adjusted for age, race, gender, and ethnicity.

Figure 1: Flowchart describing the study methods

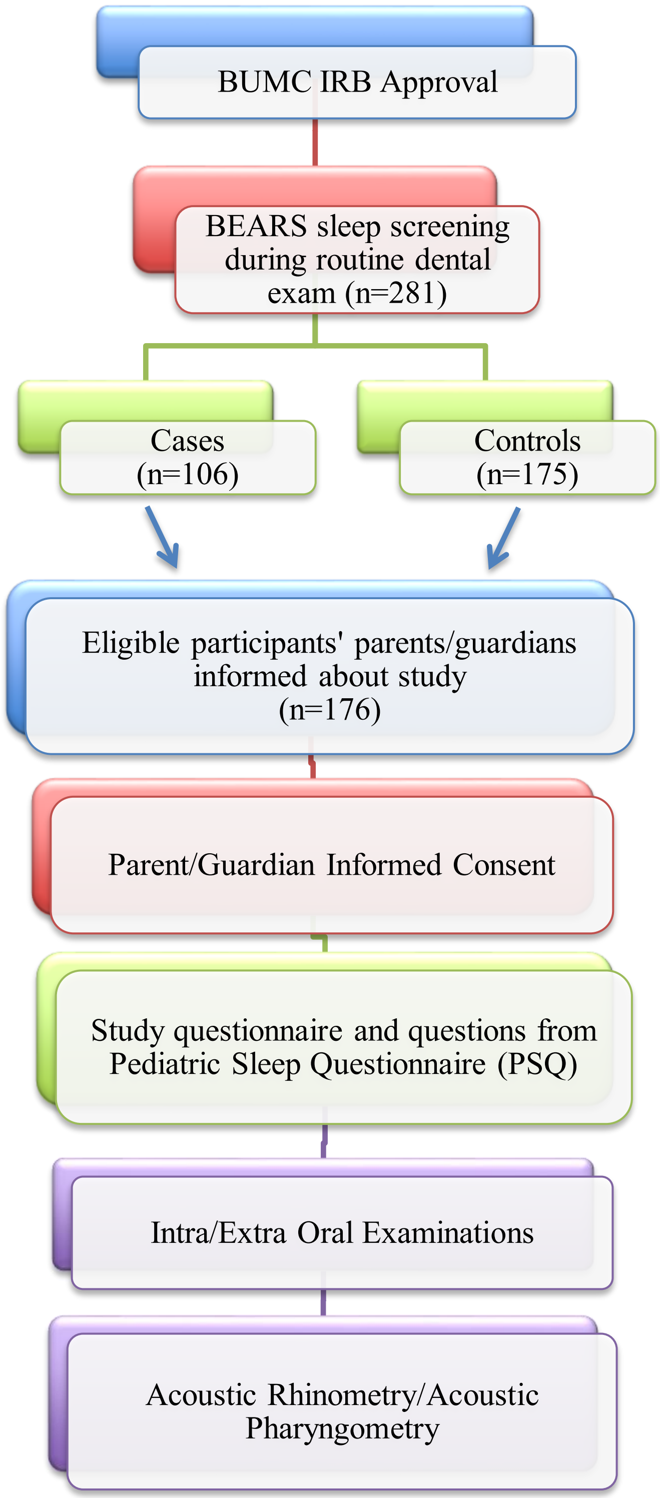

Figure 2: An example of a pharyngometry analysis segment

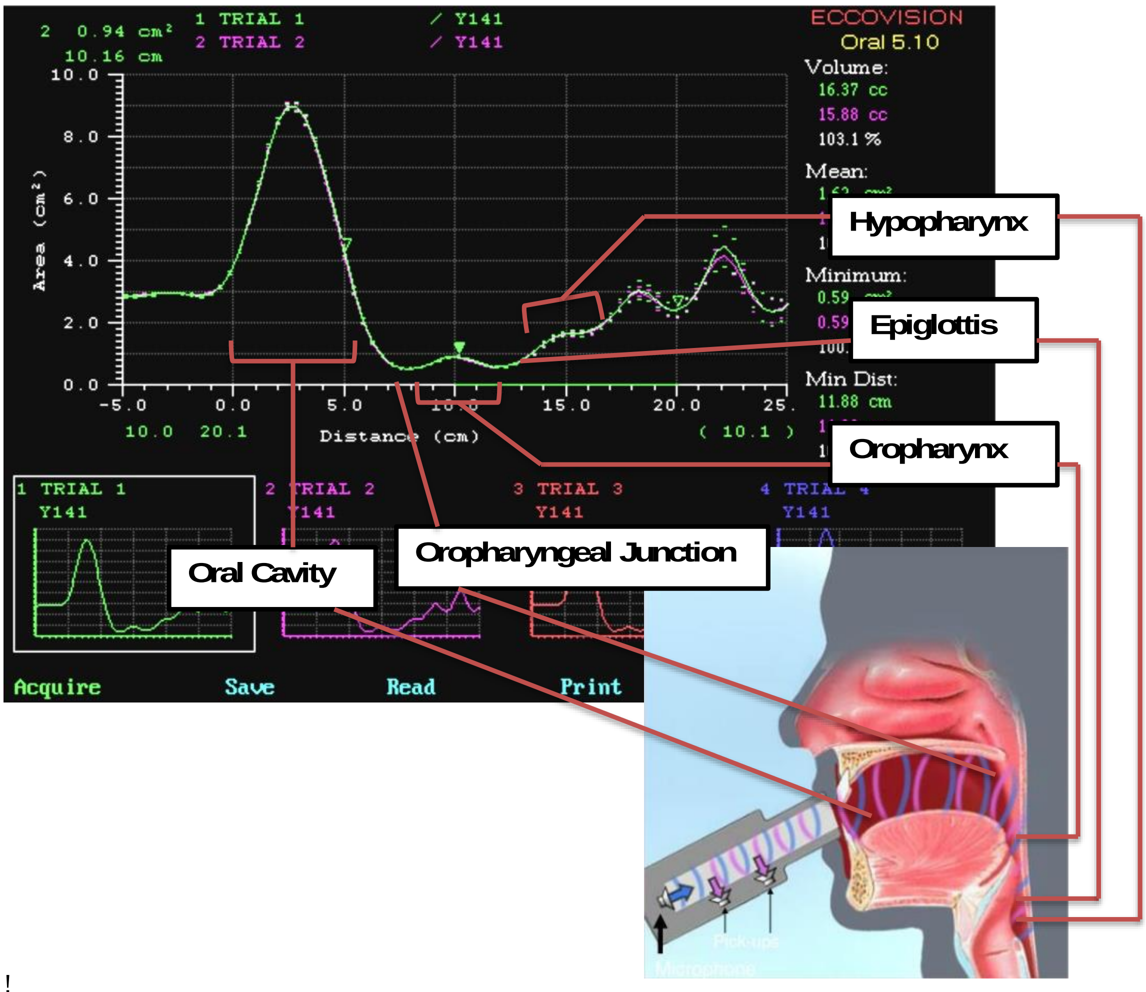

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Figure 3: An example of a rhinometry analysis segment

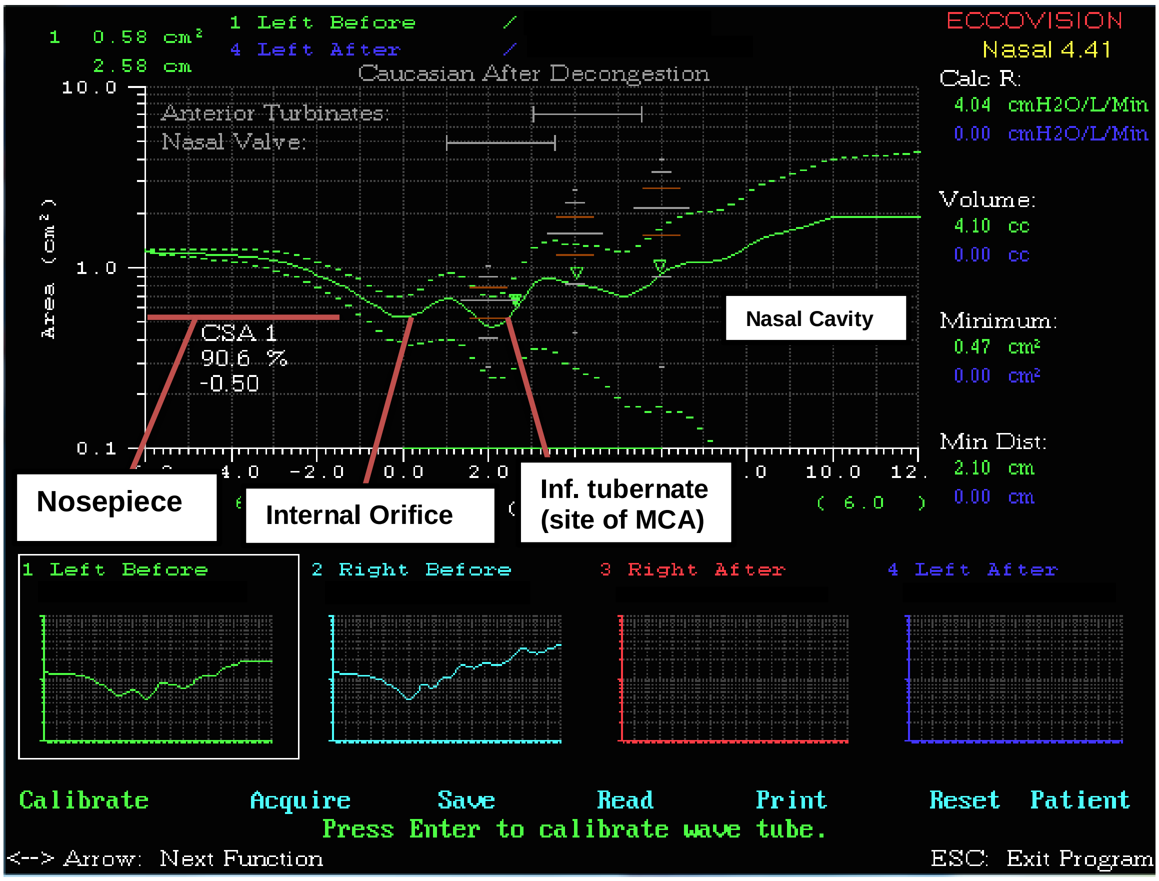


Figure 4: Eccovision acoustic rhinometer and acoustic pharyngometer system

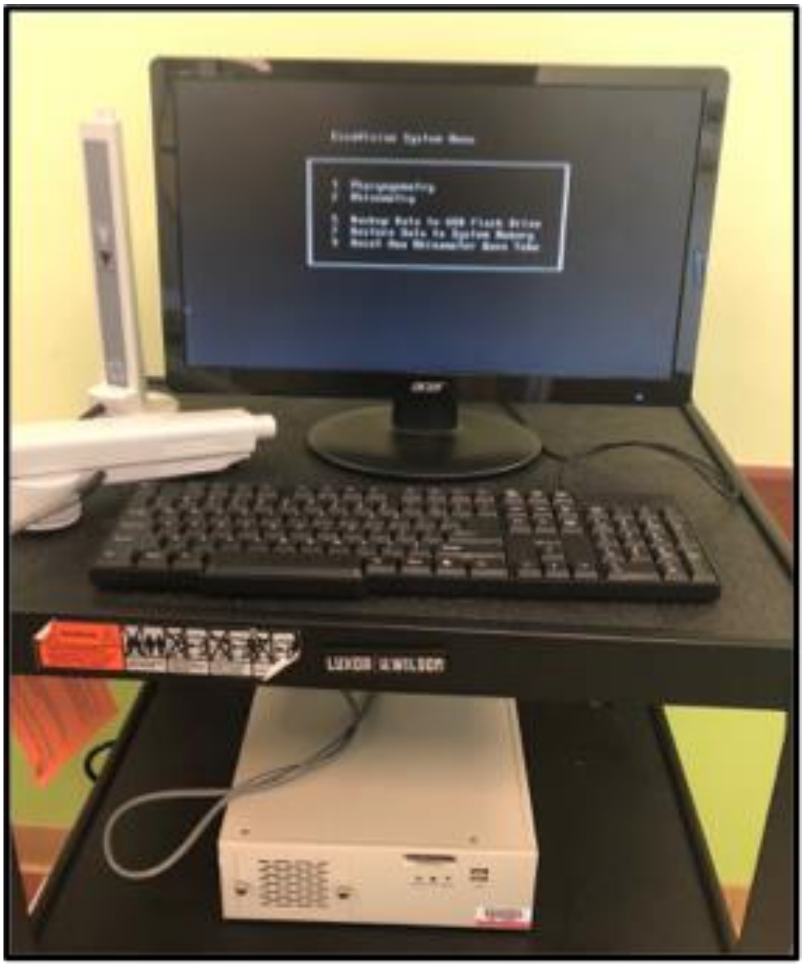


Figure 5: Acoustic rhinometer

Figure 6: Acoustic pharyngometer

RESULTS

Among the total sample of 281 children with a mean age of 9.7 years (standard deviation±3.7), the prevalence of SD was 38%. Among those with SD (n=106), 52% were between the ages of 6 and 12 years. Upper airway measurements and clinical examinations were completed for 176 children. When evaluating various parameters among the 176 children, an equal prevalence of SD was observed in both genders among cases and controls (Table 1). African-Americans and non-Hispanics recorded the highest prevalence of SD among cases and controls when compared to other racial and ethnic groups. The most common dental occlusion type among both case and control groups was class I, with class III occlusion being the least common. No statistically significant differences were observed in total pharyngeal AV or pharyngeal distance to the MCA among the different dental occlusion types (Table 2). Pharyngeal MCA was significantly higher among class III dental occlusion (1.79cm^2) than among class II and class I occlusion (1.24cm^2 and 1.01cm^2, respectively), and this was observed only among those with SD (P<.05). Furthermore, when adjusting for age, gender, race, and ethnicity in children with SD, those with class III dental occlusion had significantly larger pharyngeal MCA than those with class I and II dental occlusion (P<.05; Table 3).

In patients with SD, rhinometry MCA of both the right and left nostrils was significantly higher in class III dental occlusion compared to class I (P<.05; Table 4). Subsequently, the airway volume in both the right and left nostrils was also significantly higher among class III dental occlusion compared to class I. Nonetheless, the minimum distance to MCA appeared to be significantly larger for class I dental occlusion as compared to class III (1.45cm and 0.72cm respectively), however this was observed only in the right nostril among children with SD (Table 4). The minimum distance to MCA in the control group was significantly higher in the left nostril for class III (2.02cm) in comparison to class II (1.17cm) dental occlusion ($P<.05$). No statistically significant differences in air resistance was noted among the dental class types for both case and control groups. When adjusting for age, gender, race, and ethnicity in multivariate analysis, statistically significant differences similar to univariate analysis was observed in each of the parameters (Table 5).

Table 1: Demographic characteristics among children 3-18 years at Boston University, Boston, Massachusetts (n=281)

Variable	Cases	Controls	*P*-value
Age (years), mean±SD	9.1±4.0	10±3.5	0.06*
Gender			
Male, n (%)	53 (50.0)	87 (49.7)	0.96**
Female, n (%)	53 (50.0)	88 (50.3)	
Race			
White, n (%)	35 (33.0)	70 (40.2)	
African-American, n (%)	52 (49.1)	74 (42.5)	0.61**
Asian, n (%)	6 (5.7)	14 (8.1)	
Native Hawaiian, n (%)	1 (0.9)	1 (0.6)	
Other, n (%)	12 (11.3)	15 (8.6)	
Ethnicity			
Hispanic, n (%)	32 (30.2)	44 (25.3)	0.37**
Non-Hispanic, n (%)	74 (69.8)	130 (74.7)	
Dental Classification			
Class I, n (%)	60 (80)	97 (77.0)	
Class II, n (%)	11 (14.7)	19 (15.1)	0.80**
Class III, n (%)	4 (5.3)	10 (7.9)	

**P*-values from two sample T-tests
** *P*-values from Pearson chi-square tests

Table 2: Upper airway measurements by type of dental occlusion among children with and without sleep disturbances using acoustic pharyngometry (n=176)

Variable	**Cases**		**Controls**	
	Mean±SD	***P*-value***	**Mean±SD**	***P*-value***
Volume (cc)				
Class I	18.72±7.96		17.87±4.69	
Class II	17.99±6.17	0.17	19.18±7.83	0.64
Class III	25.93±5.04		18.23±6.05	
Minimum Cross-Sectional Area (cm^2)				
Class I	1.01±0.58		0.99±0.47	0.48
Class II	1.24±0.57	**0.02****	1.03±0.52	
Class III	1.79±0.25		1.20±0.66	
Minimum Distance (cm)				
Class I	11.12±2.21		11.49±2.35	
Class II	12.00±2.02	0.43	12.55±3.02	0.20
Class III	11.77±1.13		12.26±2.06	

**P*-values from one way-ANOVA & Kruskal-Wallis
** Significant *P*-value (<.05)

Table 3: Multivariate analysis of upper airway measurements by type of dental occlusion among children with and without sleep disturbances using acoustic pharyngometry (n=176)

Variable	Cases			Controls		
	***B*-coefficient**	**95% CI**	***P*-value***	***B*-coefficient**	**95% CI**	***P*-value***
Volume (cc)						
Class I	Ref †	-	-	Ref	-	-
Class II	-2.20	-7.52, 3.13	0.41	1.42	-1.46, 4.31	0.33
Class III	6.51	-1.63, 14.6	0.12	0.39	-3.54, 4.31	0.85
Minimum Cross-Sectional Area (cm^2)						
Class I	Ref	-	-	Ref	-	-
Class II	0.15	-0.26, 0.55	0.46	0.05	-0.21, 0.31	0.69
Class III	0.70	0.08, 1.31	**0.03****	0.22	-0.13, 0.58	0.21
Minimum Distance (cm)						
Class I	Ref	-	-	Ref	-	-
Class II	0.43	-1.10, 1.96	0.58	1.11	-0.16, 2.39	0.09
Class III	0.99	-1.35, 3.33	0.40	0.86	-0.88, 2.59	0.33

*Values adjusted for age, gender, race, & ethnicity
** Significant *P*-value (<.05)
† Reference group

Table 4: Upper airway measurements by type of dental occlusion among children with and without sleep disturbances using acoustic rhinometry (n=176)

Variable	Cases		Controls	
	Mean±SD	***P*-value***	**Mean±SD**	***P*-value***
Volume – Right Nostril (cc)				
Class I	4.10±2.04		4.21±2.60	0.60
Class II	3.49±1.63	**0.05****	4.89±3.85	
Class III	6.50±3.35		3.96±2.17	
Volume – Left Nostril (cc)				
Class I	3.86±1.89		4.47±2.52	
Class II	4.11±1.51	**0.0003****	5.52±3.58	0.27
Class III	7.90±2.86		4.16±1.43	
Minimum Cross-Sectional Area – Right Nostril (cm^2)				
Class I	0.33±0.11		0.36±0.15	
Class II	0.32±0.15	**0.02****	0.39±0.17	0.63
Class III	0.52±0.20		0.34±0.14	
Minimum Cross-Sectional Area – Left Nostril (cm^2)				
Class I	0.33±0.10		0.36±0.12	
Class II	0.37±0.08	**0.03****	0.40±0.15	0.32
Class III	0.47±0.19		0.40±0.16	
Minimum Distance – Right Nostril (cm)				
Class I	1.45±0.86		1.53±1.04	
Class II	2.45±1.54	**0.004****	1.70±1.15	0.50
Class III	0.72±0.93		1.94±1.35	
Minimum Distance – Left Nostril (cm)				
Class I	1.71±1.14		1.37±0.76	
Class II	1.73±0.81	0.24	1.17±0.72	**0.04****
Class III	0.75±0.94		2.02±1.30	
Air Resistance – Right Nostril (H_2O/1/min)				
Class I	8.32±6.35		8.39±8.01	
Class II	8.26±5.55	0.54	8.07±7.41	0.65
Class III	4.75±5.64		10.92±10.38	

Table 4 (continued): Upper airway measurements by type of dental occlusion among children with and without sleep disturbances using acoustic rhinometry (n=176)

Variable	**Cases**		**Controls**	
	Mean±SD	***P*-value***	**Mean±SD**	***P*-value***
Air Resistance – Left Nostril				
(H_2O/1/min)	9.22±6.88		7.75±5.88	
Class I	11.35±17.43	0.69	5.48±3.00	0.27
Class I	6.91±9.73		7.01±5.94	
Class III				

***** *P*-values are from one way-ANOVA & Kruskal-Wallis
** Significant *P*-value (<.05)

Table 5: Multivariate analysis of upper airway measurements by type of dental occlusion among children with and without sleep disturbances using acoustic rhinometry (n=176)

Variable	Cases			Controls		
	***B*-coefficient**	**95% CI**	***P*-value***	***B*-coefficient**	**95% CI**	***P*-value***
Volume – Right Nostril (cc)						
Class I	Ref[†]	-	-	Ref	-	-
Class II	-0.73	-2.26, 0.79	0.34	0.71	-0.71, 2.13	0.33
Class III	2.45	0.11, 4.78	**0.04****	-0.36	-2.30, 1.58	0.72
Volume – Left Nostril (cc)						
Class I	Ref	-	-	Ref	-	-
Class II	0.32	-2.44, 3.07	0.82	1.17	-0.18, 2.51	0.09
Class III	9.72	5.51, 13.94	**0.001****	-0.17	-2.00, 1.66	0.85
Minimum Cross-Sectional Area – Right Nostril (cm^2)						
Class I	Ref	-	-	Ref	-	-
Class II	-0.00	-0.09, 0.09	0.96	0.03	-0.05, 0.11	0.40
Class III	0.18	0.04, 0.32	**0.01****	-0.03	-0.14, 0.08	0.55
Minimum Cross-Sectional Area – Left Nostril (cm^2)						
Class I	Ref	-	-	Ref	-	-
Class II	0.05	-0.02, 0.13	0.15	0.04	-0.02, 0.11	0.21
Class III	0.16	0.05, 0.28	**0.01****	0.05	-0.04, 0.13	0.31
Minimum Distance – Right Nostril (cm)						
Class I	Ref	-	-	Ref	-	-
Class II	1.37	0.69, 2.06	**0.001****	0.18	-0.39, 0.75	0.53
Class III	-0.65	-1.69, 0.39	0.22	0.45	-0.32, 1.23	0.25

Table 5 (continued): Multivariate analysis of upper airway measurements by type of dental occlusion among children with and without sleep disturbances using acoustic rhinometry (n=176)

Variable	Cases			Controls		
	***B*-coefficient**	**95% CI**	***P*-value***	***B*-coefficient**	**95% CI**	***P*-value***
Minimum Distance – Left Nostril (cm)						
Class I	Ref	-	-	Ref	-	-
Class II	0.25	-0.52, 1.02	0.52	-0.25	-0.66, 0.15	0.21
Class III	-1.04	-2.22, 0.14	0.08	0.60	0.05, 1.15	**0.03****
Air Resistance – Right Nostril (H_2O/1/min)						
Class I	Ref	-	-	Ref	-	-
Class II	-0.18	-4.73, 4.37	0.94	-0.29	-4.53, 3.96	0.89
Class III	-3.41	-10.37, 3.55	0.33	2.93	-2.85, 8.70	0.32
Air Resistance – Left Nostril (H_2O/1/min)						
Class I	Ref	-	-	Ref	-	-
Class I	1.84	-5.05, 8.73	0.60	-2.16	-4.93, 0.61	0.13
Class III	-1.81	-12.34, 8.72	0.73	-0.99	-4.77, 2.78	0.60

* Values adjusted for age, gender, race, & ethnicity
** Significant *P*-value (<.05)
† Reference group

DISCUSSION

Sleep disturbances (SD) are a common occurrence among children and can be a result of neurological deficits or physiological phenomena, such as in obstructive sleep apnea (OSA), or SDB.[4,18,19] The major implications of disturbed sleep in the pediatric population include increased daytime sleepiness, mood disturbances, behavior problems, risk taking behavior, and cognitive impairment.[20] This study focused on highlighting the widespread prevalence SD among children, and evaluated the relationship between the dental occlusion and upper airway dimensions using AP and AR. Dental professionals may be among the first to diagnose sleep disorders among children, and should be cognizant of oral manifestations such as mouth breathing, gingival hyperplasia, xerostomia, increased levels of dental plaque, dental malocclusions, narrow arched palates, mandibular retrognathia, and an overall adenoid facial appearance: all of which may be indicative of the more widespread issue. The prevalence of SD was 38% in this study sample. This is much higher than the prevalence of 11% for sleep-disordered breathing (SDB) as reported in previous studies among children aged 2–8 years.[21] The difference in these estimates could be due to the wider age range of participants (3–18 years) in the given study, and because prevalence estimation was not limited to SDB but encompassed any type of SD. Racial differences may also play a role in the prevalence of sleep disordered breathing, as studies that have investigated race-related disparities in SDB reported a higher incidence of OSA among African-Americans. [22,23] In the given study the majority of patients were of African-American decent, and this may also have accounted for the difference in estimates.

When evaluating the facial pattern and upper airway dimensions, the majority of studies did not report significant differences in nasopharyngeal airway dimensions, but reported a predominantly broader oropharynx in class III skeletal patterns, and a smaller oropharynx among class II division I, however these results remained inconclusive.[24,25] This study reported statistically significant differences between class III and class I dental occlusion. This suggests that dental and skeletal patterns may relate to upper airway size differently, with a common consensus that class III dental and skeletal patterns generally exhibit the largest airway dimensions. Furthermore, few studies have reported that the position of teeth can affect airway size. Large retraction of the anterior teeth and orthodontic extractions could lead to narrowing of the upper airway, hence disrupting breathing during sleep.[26,27] In contrast, mesial movement of molars seems to create more space for the tongue posteriorly hence enlarging the upper airway dimensions.[27] This effect tends to improve the breathing condition, however, due to insufficient data this evidence needs further confirmation. In the given study, patients with class III dental occlusion had the largest airway dimensions relative to class I and II dental occlusion. In accordance with previous literature, the mesial position of the permanent mandibular first molar relative to the maxillary permanent first molar can be an initial predictor of upper airway dimensions. Thus, early diagnosis of dental malocclusions and understanding the implications of tooth migration on upper airway size among clinicians may dictate a proper treatment approach.

A previous study evaluated the pharyngeal airway measurements using acoustic pharyngometry in subjects with SDB and compared the results to a control group without SDB. [28] The investigators investigated both mean upper airway dimensions as well as MCA in both groups. They reported that habitual snorers exhibited a highly significant decrease in MCA as opposed to non-snorers (10.3%, *P*=.006). Additionally, they reported that mean upper airway dimensions among all participants was significantly correlated with mandibular length as determined by cephalometry.[28] Contrary to these findings, in the given study, SD was the outcome of observation as opposed to specifically SDB. The overall MCA was higher in controls than among children with SD in this study, but this was not statistically significant. Significant differences, however, were observed among the dental classifications within case and control groups individually.

Generally, the values recorded by the AR in the given study are somewhat similar to those of previous research. However, unlike the majority of studies which reported the average measurements of both nostrils combined, this study measured the parameters of each nostril separately to bring out the differences in the parameters of the airway between the dental occlusion classes.[29,30] The minimum distance from the MCA helps to determine the location of the MCA anatomically, making it a value of interest.[29] Interestingly, according to the findings of this study, there were statistically significant differences in the minimum distance to MCA in the right nostril among those with SD, and in the left nostril among those without SD. This observation was not previously documented, however the complexity of the human nose and variability in the amount of space in the nasal cavity has been observed in previous studies.[31]

Given that age, gender, race and ethnicity may play a role in differences between upper airway dimensions, multivariate analyses were conducted using both pharyngometry and rhinometry measures while adjusting for any potential bias that may occur from such factors. Statistically significant differences persisted in each of the different parameters being measured.

Recall bias was one of the main limitations of this study as parents may not remember exactly the details to some of the queries brought up by the sleep screening tool. This may have led to selection bias due to an erroneous classification of the children as either part of the control or case groups. Moreover, as parents are not always with their children in the same room during sleeping hours, they may be unaware of their children's sleeping patterns thus resulting in reporting bias. Observing sleep patterns of children in a clinical background or in a sleep clinic setting could decrease the likelihood of such limitations. Another limitation with using AP and AR to measure air resistance particularly is its method of calculation, as the utilized device may undervalues the accurate physiological flow of resistance that is measured in H_2O/1/min.[17] Nonetheless, using acoustics to measure airway dimensions yielded reliable results in this study that are also comparable to those given in literature. Radiographs, including lateral cephalometry, are vital and useful in the process of confirming the precise diagnosis of skeletal classifications and dimensions. Therefore, in addition to clinical examinations and acoustic measurements, future studies should include radiographic images in conjunction. Results from this study suggest a correlation between upper airway size and dental classification thus providing some suggestive evidence that using sleep surveys and the acoustic device may serve as modest preliminary screening methods. These methods can aid in early diagnoses of sleep disorders in the pediatric population thus minimizing future adverse effects on the overall health and quality of life of children. Recognizing the oral manifestations that may contribute to sleep disordered breathing and early intervention will also allow for optimum oral health. Acoustic pharyngometry can be a valuable tool for measuring upper airway dimension and determining if and how much dental and skeletal treatment will improve airway patency. For dental professionals, early detection of dental malocclusions will allow for timely and appropriate interceptive treatment.

The use of validated screening tools such as the BEARS and PSQ in this study provides a more accurate diagnosis of sleep related problems in children. Furthermore, the relatively large sample size generally increases the precision of the results, and strengthens the power and generalizability of the findings. Future studies may incorporate the use of acoustic measurements before and after interceptive or comprehensive orthodontic therapy to observe the effect of tooth migration, maxillary expansion, or mandibular advancement on airway patency.

CONCLUSIONS

Based on this study's results, the following conclusions can be made:

1. Sleep disturbances are a prevalent issue among children and adolescents aged 3-18 years.
2. There is a possible correlation between type of dental classification and upper airway dimensions among children with sleep disturbances.
3. Largest upper airway dimensions were observed in class III dental occlusion and smallest in class I dental occlusion among children with sleep disturbances.

APPENDIX 1: Medical History & BEARS Questionnaire

BU Henry M. Goldman School of Dental Medicine

PEDIATRIC MEDICAL & DENTAL QUESTIONNAIRE

TODAY'S DATE: **RECORD No:**

Patient Name:			Age:	Birthdate (MM/DD/YYYY):
Home Address:			Phone number: Home: Cell:	
Height (ft./in.):	Weight(lbs):	Gender: ☐ Male ☐ Female		Ethnicity: ☐ Hispanic ☐ Non-Hispanic ☐ Prefer not to answer

Race: ☐ White ☐ Asian ☐ Native Hawaiian or other
☐ African-American ☐ American Indian ☐ Prefer not to answer

Parent/Guardian Name:	Relationship to Patient:
Preferred language of communication:	Would you like to have an interpreter when you speak with the health care provider or team? ☐ YES ☐ NO

Highest level of education completed by parent/legal guardian:
☐ No formal schooling ☐ Primary school completed ☐ High school completed ☐ Prefer not to answer
☐ Less than primary school ☐ Secondary school completed ☐ College or University completed

MEDICAL HISTORY

1. Does your child have any **allergies** (medications, food)? If YES please explain:	☐ YES ☐ NO
2. Has your child been diagnosed with bleeding disorders, heart conditions, seizures, or cancer? If YES please explain:	☐ YES ☐ NO
3. Has your child's physician told you that your child needs antibiotic treatment prior to any dental procedure?	☐ YES ☐ NO
4. Has your child been diagnosed with any other medical condition? If YES, what is the diagnosed condition? If YES, has the above condition lasted more than 12 months?	☐ YES ☐ NO ☐ YES ☐ NO
5. Does your child <u>currently</u> use medication(s) prescribed by a doctor, other than vitamins? If YES please specify:	☐ YES ☐ NO
6. Does your child need **more** medical care, mental health or educational services than is **usual** for most children of the same age?	☐ YES ☐ NO
7. Is your child limited or prevented in any way in his/her ability to do the things that most children of the same age do?	☐ YES ☐ NO
8. Does your child need or get special therapy such as physical, occupational or speech therapy?	☐ YES ☐ NO
9. Does your child have any kind of emotional, developmental or behavioral problems for which he/she needs treatment or counseling?	☐ YES ☐ NO

10. During the past 12 months how often has the child's condition (medical, behavioral, emotional or developmental) affected his/her ability to perform daily activities in school or at home?
☐ Never ☐ Rarely ☐ Usually ☐ Always ☐ Don't know

11. Does your child experience difficulty with any of the following:
☐ Breathing (Respiratory problems) ☐ Hearing ☐ Eyesight ☐ Sleeping
☐ Self-care (eating/dressing/bathing) ☐ Paying attention/listening
☐ Speaking/communicating verbally ☐ Anxiety/depression

12. Does your child see a specialist(s) to receive treatment for any condition listed above? If YES, please complete the following: Doctor's name: Specialty field: Doctor's Phone number:	☐ YES ☐ NO

13. Does your child have any of the listed habits? (currently or had in the past)
☐ Thumb sucking ☐ Mouth breathing ☐ Tongue thrusting ☐ Nail-biting ☐ Teeth grinding

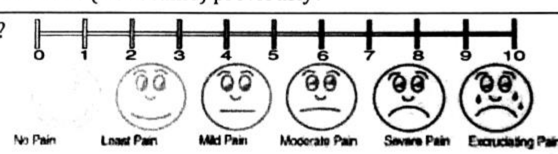
14. Does the child have trouble sleeping or has the child been diagnosed with a sleeping disorder by a health professional?	☐ YES ☐ NO
15. Is the child on a special diet?	☐ YES ☐ NO
16. Does the child currently use a baby bottle to drink milk? If YES, does the child sleep with the bottle?	☐ YES ☐ NO ☐ YES ☐ NO

17. How often does the child drink apple juice, carbonated drinks (sodas), lemonade or other soft drinks?
☐ ≥2 /day ☐ 1 /day ☐ ≥2/week ☐ 1 /week ☐ ≥2/month ☐ 1/month ☐ Never

18. How often does the child eat snacks between meals?
☐ ≥2 /day ☐ 1 /day ☐ ≥2/week ☐ 1 /week ☐ ≥2/month ☐ 1/month ☐ Never

DENTAL HISTORY & ORAL HEALTH

19. Is this the child's first visit to a dentist? If NO, what is the date of last dental exam (mm/dd/yyyy):	☐ YES ☐ NO
20. Does the child have a dental problem today?	☐ YES ☐ NO
21. Has the child ever received local anesthetic (Novocaine) previously?	☐ YES ☐ NO
22. Is the child experiencing pain today? If YES, please ask child to select the level of pain	☐ YES ☐ NO



23. During the past 3, months how much pain or distress have your teeth or gums caused you?
☐ A great deal ☐ Quite a bit ☐ Some ☐ A little bit ☐ Not at all

24. In the past 3 months, has the child had difficulty eating normally because of dental pain/problems?	☐ YES ☐ NO
25. In the past 3 months, how often did the child feel self-conscious, nervous or unhappy because of problems in the mouth, teeth or gums?	☐ Never ☐ Sometimes ☐ Always
26. In the past 3 months, has the child missed school because of pain or discomfort in the teeth or mouth? If YES how often: ☐ Once/month ☐ 2 times/month ☐ 3 times/month ☐ >3 times/month	☐ YES ☐ NO
27. Who brushes the child's teeth?	☐ CHILD ☐ PARENT ☐ OTHER
28. How many times per day does the child brush his/her teeth?	☐ 0 ☐ 1 ☐ ≥2
29. Does the child use fluoride based toothpaste?	☐ YES ☐ NO ☐ DO NOT KNOW
30. How many times per day does the child floss his/her teeth per day?	☐ 0 ☐ 1 ☐ ≥2
31. Does the child drink tap water?	☐ YES ☐ NO
32. Is the tap water at home fluoridated?	☐ YES ☐ NO ☐ DO NOT KNOW

COMPLETE ONLY **ONE TABLE** BELOW BASED ON CHILD'S AGE

P – Questions to be directed to **parent**; C – Questions directed to **the child**

TABLE A	**Preschool (2 – 5 YEARS)**		
Bedtime problems	Does your child have any problems going to bed?		☐ YES ☐ NO
	Falling asleep?		☐ YES ☐ NO
Excessive day-time sleepiness	Does your child seem over tired or sleepy a lot during the day?		☐ YES ☐ NO
	Does your child still take naps?		☐ YES ☐ NO
Awakenings during night	Does your child wake up a lot at night?		☐ YES ☐ NO
Regularity and duration of sleep	Does your child have a regular bedtime and wake time?		☐ YES ☐ NO
	What are they?	Bedtime	am/pm
		Wake-time	am/pm
Sleep-disordered breathing	Does your child snore a lot or have difficulty breathing at night?		☐ YES ☐ NO
	Does your child breathe mainly through the nose or mouth?	☐Nose ☐Mouth ☐Don't know	

TABLE B	**School-aged (6 – 12 YEARS)**		
Bedtime problems	Does your child have any problems at bedtime? (P)		☐ YES ☐ NO
	Do you have any problems going to bed? (C)		☐ YES ☐ NO
Excessive day-time sleepiness	Does your child have difficulty waking in the morning, seem sleepy during the day or take naps? (P)		☐ YES ☐ NO
	Do you feel tired a lot? (C)		☐ YES ☐ NO
Awakenings during night	Does your child seem to wake up a lot at night? Any sleep walking or nightmares? (P)		☐ YES ☐ NO
	Do you wake up a lot at night? Have trouble getting back to sleep? (C)		☐ YES ☐ NO
Regularity and duration of sleep	How many hours of sleep does the child get?	School day	hours
		Weekend	hours
	Do you think he/she is getting enough sleep? (P)		☐ YES ☐ NO
Sleep-disordered breathing	Does your child have loud or nightly snoring or any breathing difficulties at night? (P)		☐ YES ☐ NO
	Do you breathe mainly through the nose or mouth (C)?		☐Nose ☐Mouth ☐Don't know

TABLE C	**Adolescent (13 – 18 YEARS)**		
Bedtime problems	Do you have any problems falling asleep at bedtime? (C)		☐ YES ☐ NO
Excessive day-time sleepiness	Do you feel sleepy a lot during the day? In school? While driving (if applicable)? (C)		☐ YES ☐ NO
Awakenings during night	Do you wake up a lot at night?		☐ YES ☐ NO
	Have trouble getting back to sleep? (C)		☐ YES ☐ NO
Regularity and duration of sleep	What time do you usually go to bed on school nights? Weekends?	School night	am/pm
		Weekend	am/pm
	How much sleep do you usually get? (C)		hours
Sleep-disordered breathing	Does your teenager snore loudly or nightly? (P)		☐ YES ☐ NO
	Do you breathe mainly through the nose or mouth (C)?		☐Nose ☐Mouth ☐Don't know

APPENDIX 2: Pediatric Sleep Questionnaire

Sleep and breathing patterns in childhood
Study Questionnaire

Background Information:

1. Today's date (mm/dd/yy):
2. Name:
3. Date of birth (mm/dd/yy):
4. Age (years):
5. Gender:
6. Height (cms):
7. Weight (kgs):
8. Race/ethnicity:
   ☐ White ☐ African-American ☐ Asian ☐ American Indian ☐ Native Hawaiian/ other
9. Ethnicity:
   ☐ Hispanic ☐ Non-Hispanic
10. Living with parents? ☐ Yes ☐ No
11. Schooling: ☐ Home-schooling ☐ Schooling outside
12. Smoking at home/Parental smoking ☐ Yes ☐ No
13. If yes to 12 then please answer the following:

    ☐ One parent smokes

    ☐ Both parents smoke
14. Has your child been diagnosed with ADD/ADHD (Attention deficit disorders)?

    ☐ Yes ☐ No

15. Has your child been diagnosed with any medical condition? ☐ Yes ☐ No

16. If YES to 13 is your child taking medications for this condition? ☐ Yes ☐ No

17. Does your child have a history of allergies? ☐ Yes ☐ No

18. Does your child currently have seasonal allergies? ☐ Yes ☐ No

19. Does your child use any medications currently to control allergies? ☐ Yes ☐ No

20. Does your child currently have a nasal congestion (common cold)? ☐ Yes ☐ No

21. Does your child have breathing difficulties? ☐ Yes ☐ No

Pediatric Sleep Questionnaire (PSQ):

22. While sleeping, does your child....

   a. Snore more than half the time? ☐YES ☐NO

   b. Always snore? ☐YES ☐NO

   c. Snore loudly? ☐YES ☐NO

   d. Have ``heavy" or loud breathing? ☐YES ☐NO

   e. Have trouble breathing, or struggle to breathe? ☐YES ☐NO

   f. Have you ever seen your child stop breathing during the night? ☐YES ☐NO

23. Does your child ....

   a. Tend to breathe through the mouth during the day? ☐YES ☐NO

   b. Have a dry mouth on waking up in the morning? ☐YES ☐NO

   c. Occasionally wet the bed? ☐YES ☐NO

   d. Wake Up feeling unrefreshed in the morning? ☐YES ☐NO

   e. Have a problem with sleepiness during the day? ☐YES ☐NO

   f. Have a teacher or other supervisor who commented that ☐YES ☐NO your child appears sleepy during the day?

g. Find it hard to wake your child up in the morning? ☐YES ☐NO

h. Wake up with headaches in the morning? ☐YES ☐NO

24. Did your child stop growing at a normal rate at any time since birth? ☐YES ☐NO

25. Is your child overweight? ☐YES ☐NO

26. This child often.....

a. Does not seem to listen when spoken to directly. ☐YES ☐NO

b. Has difficulty organizing task and activities. ☐YES ☐NO

c. Is easily distracted by extraneous stimuli. ☐YES ☐NO

d. Fidgets with hands or feet or squirms in seat. ☐YES ☐NO

e. Is `on the go' or often acts as if `driven by a motor'. ☐YES ☐NO

f. Interrupts or intrudes on others (e.g. butts into conversations or games). ☐YES ☐NO

Clinical Examination:

27. Patient profile:

28. Observed breathing pattern:

☐ Mouth only
☐ Nose only
☐ Both

29. Nasal septum deviation:

☐ Yes ☐ No

30. Any nasal obstruction (due to trauma or other medical reasons)?

☐ Yes ☐ No

31. Skeletal classification:

- ☐ Class 1 (Maxillary mandibular dental protrusion or retrusion)
- ☐ Class 2 (Maxillary protrusion and/or mandibular retrognathism)
- ☐ Class 3 (Maxillary retrognathism and/or mandibular protrusion/prognathism)

32. Dental classification:

- ☐ Class I (normal alignment of upper and lower teeth
- ☐ Class II (Maxillary protrusion present/Upper teeth are more forward/Convex appearance
- ☐ Class III (Mandibular protrusion present/Lower teeth are more forward/Concave appearance

33. Transverse maxillary evaluation:

- ☐ Maxillary constriction with unilateral posterior cross-bite
- ☐ Maxillary constriction with bilateral posterior cross-bite
- ☐ Maxillary constriction without posterior cross-bite

34. Vertical evaluation of patient (for orthodontic patients with cephalograms)

- ☐ Hypo-divergent vertical pattern
- ☐ Normo-divergent vertical pattern
- ☐ Hyper-divergent vertical pattern

35. Nasal airway measurement:

____

____

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36. Pharyngeal measurement:

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Thank you for your participation!

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