ANALYSIS OF THE RELATIONSHIP BETWEEN THE POSTERIOR AIRWAY SPACE AND MOLAR CLASSIFICATION IN CHILDREN AGED 10-15

By

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To my family, friends and teachers

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LIST OF ABBREVIATIONS

ANB	A cephalometric measurement of angle between A point and B point
CBCT	Cone beam computerized tomography
DICOM	Digital imaging and communications in medicine
IRB	Institutional review board
OSA	Obstructive sleep apnea
SNA	Sella, nasion, A point angle
SNB	Sella, nasion, B point angle
SN-GoGn	Sella, nasion to gonion, gnathion also known as mandibular plane angle
UFCD	University of Florida College of Dentistry

Abstract of Thesis Presented to the Graduate School
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In this study we investigated the difference in the posterior airway volume, area and minimum axial area between patients with Class I, Class II, and Class III dental malocclusions as well as patients with cleft lip with or without cleft palate aged 10-15. While numerous studies have examined the relationship between mandibular retrognathia and the anatomy of the posterior airway, few have specifically addressed the relationship between molar occlusion and posterior airway anatomy, and none have done so in children. Since a class II molar relationship predominates in mandibular retrognathia, we suspected that there should be a similar relationship between anatomy and molar occlusion.

Subjects were found by a retrospective search of the Digital Imaging and Communications in Medicine (DICOM) folder of University of Florida College of Dentistry (UFCD) Department of Orthodontics after IRB approval was obtained. We started with an initial goal of finding 100 patients to be split into 4 separate categories. 25 Class I, Class II and Class III dental malocclusion patients were found, but only 19 cleft lip with or without cleft palate patients were found in the database. The total number of subjects in our study was therefore only 94. Age at scan, sex, race, right

molar classification and left molar classification were recorded for each subject based on their dental chart. Cephalometric measurements were made from lateral cephalometric x-rays produced from CBCT data by the Dolphin Imaging Suite v.11. SNA, SNB, ANB and Sn-GoGn were recorded. Airway data was also calculated by the same imaging software based on volume renders the software built based on recorded CBCT data. The posterior airway was drawn from the following 4 points, Basion, ANS, the most lateral inferior portion of C2 and menton. The upper and lower borders for minimum axial area were then defined and the upper and lower limits of the "box." Total airway volume, total airway area and minimum axial area were recorded for each subject.

Pearson and Spearman correlation coefficients showed that SNB and ANB were properly related to molar score. There were no statistically significant differences were found between groups for any of the variables examined other than SNA (ANOVA $p=0.0232$) and ANB (ANOVA $p<0.0001$). The best four variable model was age at scan, sngogn, Class II and sex ($R^2 = 0.11$).

Molar occlusion was not significantly related to airway area, airway volume or minimum axial area. The sample size was small and since this was a retrospective study, additional data (such as height, weight) that could be influencing the results, were not available. Additionally, most of these scans were taken for orthodontic indications, such as ectopic eruption of canines, which could have an impact on molar classification. A more homogenous sample might yield different results.

The goal of this pilot study was to assess if molar occlusion could be used as a clinical indicator of patients with different posterior airway anatomy. The study, however, with its limited sample size found no relationship between molar occlusion and the posterior airway. Larger studies with control over additional variables could yield different results.

CHAPTER 1
INTRODUCTION

Multiple studies have shown that airway problems are significantly related to different types of malocclusions and can cause different dentofacial anomalies.[1,2] Patients with class II malocclusion have been shown to have smaller oropharyngeal volumes than class I and class III patients.[3] In patients with obstructive sleep apnea, for example, the size and position of the mandible is different, there is an enlargement of the posterior airway space and size of the tongue and the soft palate is different from those that are unaffected.[4] For the most part, the airway assessment in these patients has been done on two-dimensional lateral cephalograms.[5] The lateral cephalogram, however, is not an ideal instrument to make airway assessments[6] because it is cannot identify the soft tissue contour of the airway in the axial dimension. Cone beam computerized tomography (CBCT) scanning is a more useful adjunct in diagnosing airway disorders because it can also take into account the axial plane - which is also physiologically the most relevant.[7,8] An additional benefit to CBCT is that it exposes the patient to reduced radiation than a conventional medical CT. Acrylic model reproduction of CBCT data has shown to be reliable and accurate when compared to software made measurements.[9]

Due to its inability to definitively diagnosis the disorder, CT imaging is not routinely used in the work up for a patient with OSA. Despite this, it clearly has a role in providing definitive imaging of the soft tissue and bony structures that can be risk factors for OSA.[10] Some authors, however, promote its usage for diagnosis by looking in deviations from normal in the oropharnyx,[11] retropharyngeal tissue[12] or palate, uvula, and lingua.[13] As of late there has been a large push to use cone beam CT (CBCT) imaging for routine diagnostic orthodontic imaging. CBCT yields additional useful information in treatment planning with low additional radiation and exposure risk to patients. It also has very little magnification and greater anatomical reproducibility, approximately 1% and 1mm, respectively, than the standard panoramic and lateral cephalometric x-rays.[14] Relevant to OSA, it has also been shown that patients of different craniofacial patterns on which the orthodontist focuses his therapy have differing posterior airway space volumes, as would make sense based on the position of the lower jaw in these different craniofacial patterns. For example, patients with Class II craniofacial patterns have a significantly narrower pharyngeal airway than those with Class III craniofacial patterns.[15] Additionally, studies analyzing orthodontic treatment with mandibular repositioning appliances have found that they improve and reduce the symptoms of OSA by enlarging the pharynx in the lateral plane at the retropalatal and retroglossal levels of the pharynx.[16] Others have found enlargement in the upper airway as well, with statistically significant expansion in the naso-oropharynx area ($p<.014$; $p<.050$) and in the angle between the hard and the soft palate ($p<.001$).[17]

The goal of this project was to examine if a relationship exists between different malocclusions and the anatomy of the posterior airway. As detailed above, the existing literature has shown that there is a relationship between mandibular retrognathia and posterior anatomy. Since class II maloclussion predominates in mandibular retrognathia, it should also be negatively correlated to the anatomy of the posterior airway. This project will also add to the current literature by including a population with craniofacial anomalies which might be able to show how deficient growth processes can affect the volume of the posterior airway. This project will also help to support or refute the relatively small body of literature - few studies with relatively small sample sizes - that exist on this topic. Additionally, this study also looked for variations amongst different ethnic groups and for children in the age group 10-15, the population most relevant to practicing orthodontists. Importantly, the pharyngeal structures grow rapidly until 13 years of age and followed by a quiescent period for children aged 14-18. This study will hopefully be able to relate some of this change to changes in malocclusion. Our null hypothesis was that there are no significant relationships between posterior airway volume and malocclusion in children and adolescents aged 10-15. Our alternative hypothesis was that there are significant relationships between posterior airway volume and malocclusion in children and adolescents aged 10-15.

CHAPTER 2
METHODS

After IRB approval was obtained, the DICOM folder of the UFCD Department of Orthodontics was reviewed with the goal of obtaining 100 subjects. To be included in the study, subjects were identified as aged 10-15 and had to have a complete CBCT scan. Subjects were excluded from the study if they had any missing teeth, insufficient CBCT data, were outside the age range, or had any medical condition which in the opinion of the investigators results in a deviation from a normal grown pattern, other than cleft lip with or without cleft palate. Subjects were to be placed into 3 groups based upon their occlusion, until each group had 25 subjects. Only 19 patients with cleft lip with or without cleft palate that fulfilled our inclusion criteria existed in the database, so our final sample consisted of 94 subjects. In addition to right and left molar occlusion, age at CBCT, date of birth, sex and race were recorded based on information provided in the patient's dental chart. Each subjects CBCT was then used by the Dolphin Imaging Suite v.11 to produce a lateral cephalometric x-ray and a volume render of the posterior airway. SNA,SNB, ANB and Sn-GoGn were the cephalometric values recorded for each subject. The posterior airway was drawn by connecting the following 4 points, Basion, ANS, the most lateral inferior portion of C3 and menton. (Figure 2-1) The upper and lower borders for minimum axial area were then defined as the upper and lower limits of Basion –ANS and C3-menton. (Figure 2-2). Molar class was scored as Class II full cusp = 1, Class II ¾ cusp = 2, Class II ½ cusp = 3, Class II ¼ cusp = 4, Class I = 5, Class III 1/4 cusp = 6, Class II ½ cusp = 7, Class II 3/4 cusp = 8 and Class III full cusp = 9. The data was analyzed by ANOVA, Kruskal-Walls, Pearson and Spearman correlation coefficients. Linear regression was used to examine the relationship between minimum axial area and demographic characteristics, molar class, and cephalometric measures. A p-value of 0.05 was considered statistically significant.

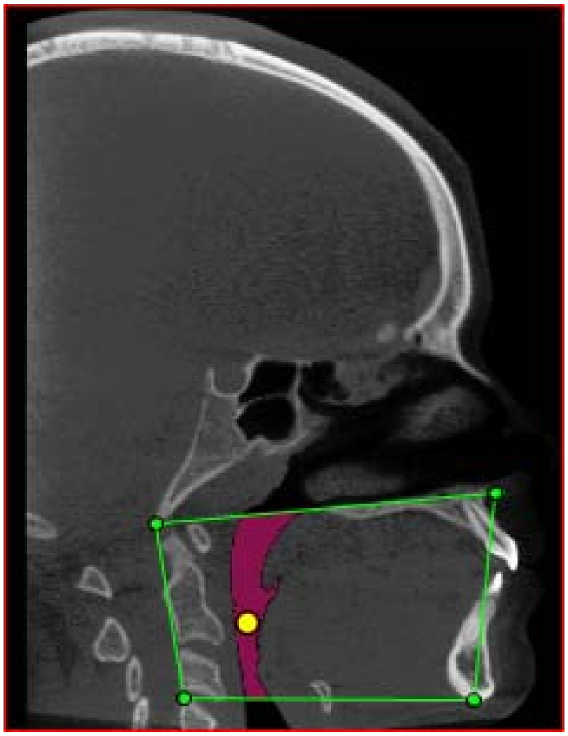

Figure 2-1.   Borders of airway

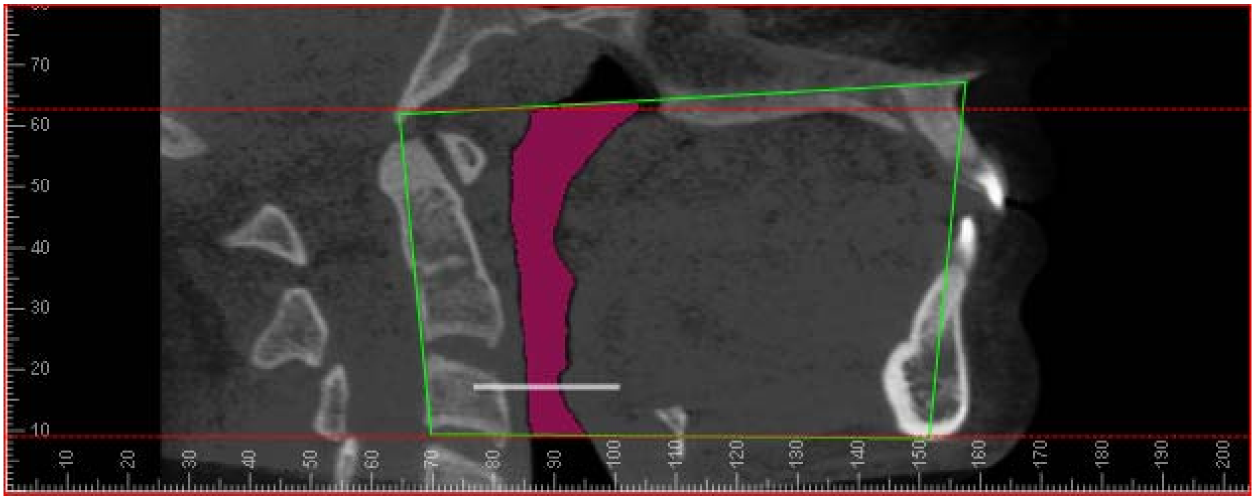

Figure 2-2.   Maximum and minimum borders of airway with minimum axial area

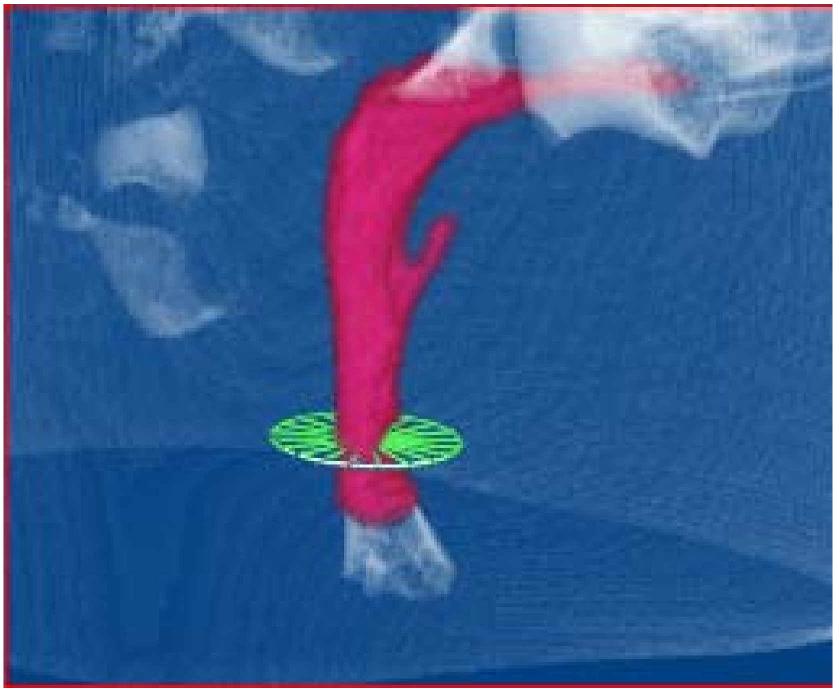

Figure 2-3. Volume render of airway

CHAPTER 3
RESULTS

There were 94 subjects in our sample. Fifty were female and 44 were female. There were 23 subjects in the African American and Asian category and 71 subjects were included in the Caucasian and Hispanic category. No differences were found within groups for either sex or race with chi square p-values of of 0.54 and 0.72, respectively (Figures 3-1 and 3-2). There were no differences between groups for the variables age at scan (p=0.19), SNB (p=0.24), Sn-GoGn (p=0.16), airway area (p=0.77), airway volume (p=0.24) and minimum axial area (p=0.49), while there were for SNA and ANB (Tables 1-3). The ANOVA p-value for SNA was 0.02 and by the Kruskal-Walls test was 0.04. The ANOVA p-value and Kruskal-Walls p-value for ANB were both <0.0001. The significance of ANB is intuitive because ANB is the cephalometric measurement most involved in jaw relationship, which is a difference we were specifically aiming to create between our groups. The SNA difference could also be explained by our study design, as cleft patients and class III patients tend to have a degree of maxillary hypoplasia. By the Pearson correlation coefficient, molar scores were properly related to SNB and ANB (p-value of <0.0001). ANB was negatively correlated and molar score was positively correlated with p-values of 0.0049 and 0.0224 to the age at scan. This was expected with our sample as molar occlusion tends to class I as the child loses their primary teeth and moves to the permanent dentition. ANB, is also known to decrease as the mandible grows as the child ages. Age at scan was also highly correlated, p-value <0.0001, with the airway area and mildly correlated with airway volume (p-value <0.0001) and minimum axial area (p-value 0.0047). (Table 3-4) Airway size has also been shown elsewhere in the literature to increase with increasing age.

Spearman correlation coefficients yielded similar results. We used linear regression to try and find the variables that would best fit our data points. Our four best models were: 1 variable model: age at scan ($R^2 = 0.08$), 2 variable model: age at scan, sngogn ($R^2 = 0.10$), 3 variable model: age at scan, sngogn, Class II ($R^2 = 0.11$), 4 variable model: age at scan, sngogn, Class II, sex ($R^2 = 0.11$). In our best 2 models, only age at scan was significant.

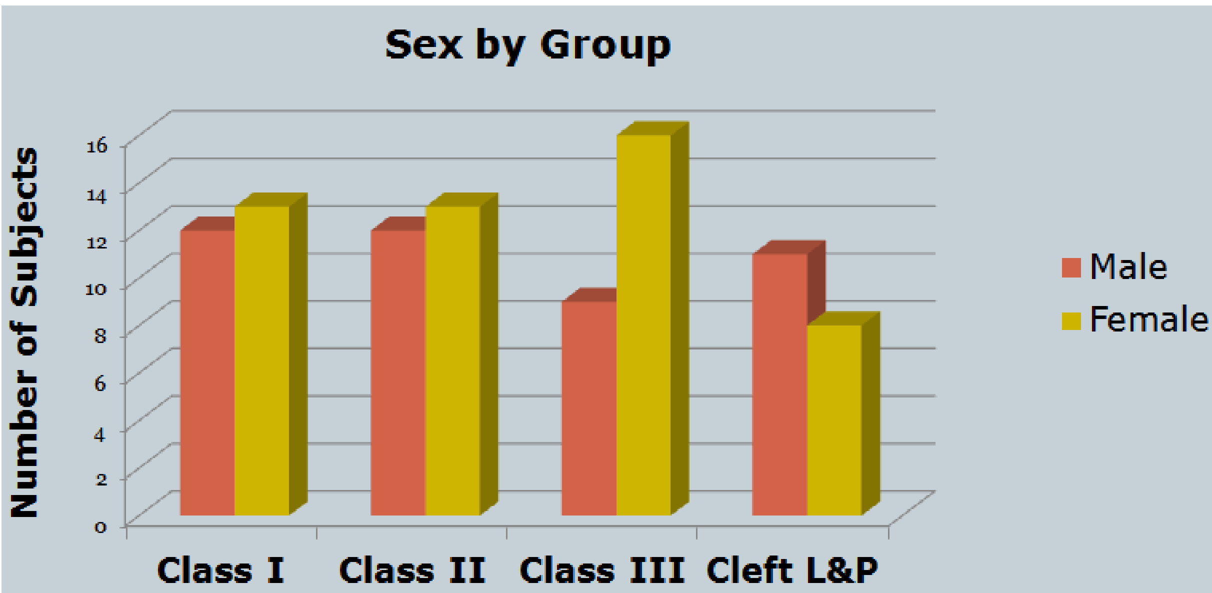

Figure 3-1. Sex by group

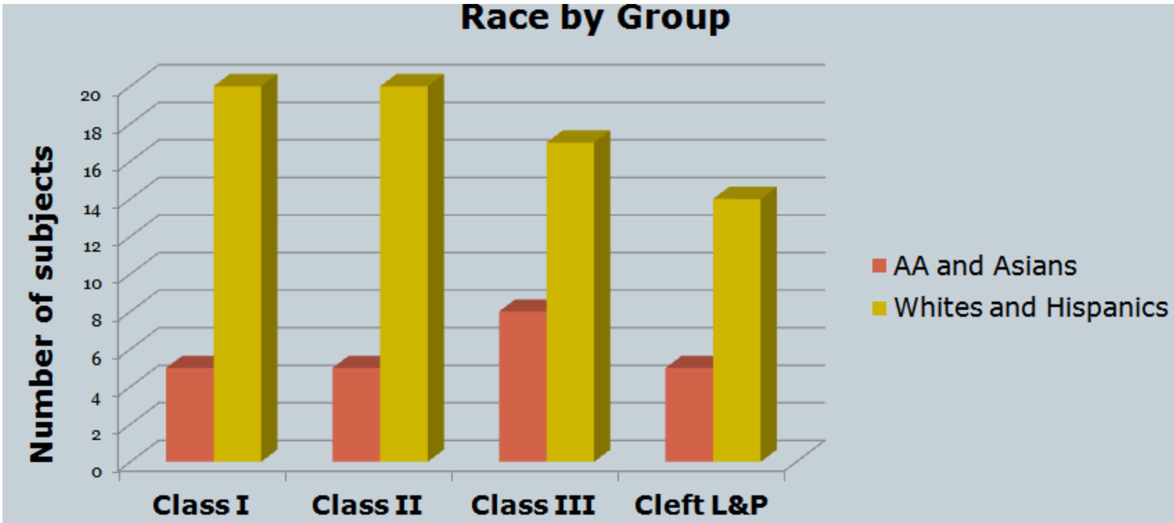

Figure 3-2. Race by group

Table 3-1. Variability amongst groups.

Molar class group	Mean age	Minimum	Maximum
Class I	13.1	10.8	15.5
Class II	12.5	10.2	15.6
Class III	13.4	10.8	15.5
Cleft lip and palate	12.9	11	15.9
ANOVA P-value	0.2		

Table 3-2. Variability amongst groups.

Molar class group	SNA	SNB	ANB	Sn-GoGn
Class I	83.5 (4.1)	79.4(3.2)	4.1(2.5)	32.8(4.3)
Class II	84.4(5.0)	78.5(4.4)	5.9(2.7)	32(5.4)
Class III	81.1(5.5)	80.5(5.8)	0.6(3.5)	36.0(7.7)
Cleft lip and palate	80.3(5.7)	77.8(5.1)	2.4(3.8)	33.9(7.8)
ANOVA P-value	0.02	0.2	0.0001	0.16

Table 3-3. Variability amongst groups.

Molar class group	Airway area mm^2	Airway volume mm^3	Minimum area mm^2
Class I	609.2 (180.1)	13261 (5131.8)	153.7 (82.4)
Class II	591.8 (216.9)	12741 (7153.1)	126.2(87.4)
Class III	629.2 (176.8)	14018 (5642)	161.7(86.7)
Cleft lip and palate	571.6 (178.6)	12668 (6718.4)	139(93.2)
ANOVA P-value	0.77	0.24	0.49

Table 3-4. Pearson correlation coefficients age at scan

	Molar score	SNA	SNB	ANB	Sn-GoGn	Airway area mm^2	Airway volume mm^3	Minimum axial area mm^2
Age at scan	0.29	-0.13	0.04	-0.24	0.034	0.43	0.46	0.29
P-value	0.0049	0.21	0.68	0.02	0.73	<0.0001	<0.0001	0.005

Table 3-5. Pearson correlation coefficients molar score.

	SNA	SNB	ANB	Sn-GoGn	Airway area mm^2	Airway volume mm^3	Minimum axial area mm^2
Molar score	-0.13	0.30	-0.56	0.18	0.12	0.09	0.12
P-value	0.23	0.003	<0.0001	0.08	0.22	0.40	0.27

CHAPTER 4
DISCUSSION

Based on our results, we fail to reject our null hypothesis. In our sample, there was no relationship for children aged 10-15 between molar occlusion and the volume, overall area or minimum axial area of the posterior airway. These results are particularly disappointing, because numerous studies have shown that a relationship exists between the position of the lower jaw and the posterior airway. Since the lower jaw also controls the position of the lower molar, which determines molar classification, it follows that molar classification should be related to the posterior airway. There was a significant difference between our groups when it came to the relationship between the jaws, which we evaluated cephalometrically through ANB. Other published studies seem to contradict our results.

In a sample of 27 children, Kim et al., when looking at ANB, did find that mean total airway volume, from the epiglottis up the nasopharynx to the nasal cavity, was significantly smaller in mandibular retrognathic patients than those with a normal anteroposterior skeletal relationship. Our study did not include the nasal cavity within its measurement. Additionally, in support of our results, the total volume measurements of the 4 subregions of the airway were not statistically significant between the 2 groups that they examined, class I and class II patients. This study only examined ANB and not molar occlusion.[18]

Other studies tried to find relationships between the airway and class III skeletal malocclusion patients. Hong et al. in a sample of 60 subjects with a mean age of 26 +/- 4.5 years found that in their class III subjects, the lower part of the pharyngeal airway and the volume of the upper part of the pharyngeal airway were greater than in their

Class I malocclusion patients. There was a negative correlation between the upper part of the pharyngeal airway with ANB and the Wits appraisal. There was a positive correlation between the volume and SNB, APDI, pogonion to Nasion perpendicular, gonial angle and FMA.[19]

Iwasaki et al. did examine dental malocclusion. They found that the Class III group showed statistically larger oropharyngeal area and width compared with the Class I group. Class III severity was positively correlated with area in a study of 45 children. Their sample however, had a lower average age 8.6 +/-1.0 years and used different borders to define the airway than we did in our study.[20]

Grauer et al. in a study of 62 patients (mean age approximately 25) found a statistically significant relationship between anteroposterior jaw relationship and the volume of the inferior component of the airway. The investigators also found statistically significant relationships between airway volume and the size of the face with regard to sex. [21] El et al. in a sample of 101 patients found that there was a significant difference for the oropharyngeal volume for the Class III mandibular protrusion patients and the Class II mandibular retrusive subjects had the lowest values. Their minimum axial area was the variable that was best correlated with Oropharyngeal airway volume.[22]

Not all studies in the published literature contradict our results . Alves et al., in an study of 60 adult subjects (all patients above the age of 15) found similar results to ours. While the class III group had a larger area and volume and the class II group had a smaller area and volume, the results revealed that the majority of airway measurements were not affected by degree of malocclusion and no statistical significance was found.[23]

Unfortunately, there is little uniformity amongst these studies and most of the studies were done with adult subjects. The studies used different borders for their airways – some included the nasal cavity as well, some divided the airway into three planes and some used the same borders as our study. The studies also used different CBCT scanners, all of which have different resolutions which could impact the volume produced by the different studies' software programs. Additionally, most studies used different software programs to analyze and build the airways.

We therefore have identified a few possible confounders that could explain our results as would be importance if other studies were to be pursued. First, our sample size was small and not ideally homogenous. Due to the retrospective nature of our study, we were forced to utilize the patients we had in our database. We used the full range of molar classification, for example, from ¼ cusp to full cusp and beyond. Perhaps a sample that consisted of only full cusp occlusions would yield different results. Another possible confounder could be the children's weight. Numerous studies have shown a link between obesity and decreased posterior volume – and obstructive sleep apnea. Height and weight were unknown variables in our study because they were not part of the patient's charts. A third confounder was that most of these scans were taken for orthodontic indications. CBCT's are not taken as a routine diagnostic aid in the UFCD Orthodontic Clinic. Many of these patients had scans taken due to the presence of impacted teeth, predominantly canines. An impacted canine, in the maxilla and mandible can impact molar occlusion, in either direction, depending on its location. An additional problem could be our software itself, as the Dolphin Imagine Suite v.11 may be unable to detect differences that would be significant based on the proprietary algorithms it uses to make its calculations. We also did not record overjet, which may possibly have been a better indicator of the jaw relationships than molar occlusion. We also did not assess if patients had symptoms of upper respiratory infection, pharyngeal pathology such as adenoid hypertrophy and tonsillitis or a history of adenoidectomy or tonsillectomy. Lastly, despite calibration over multiple scans, there is always the possibility of investigator error.

Future studies will hopefully take these confounders into account. In the investigators opinion, an ideal study would be one in which a prospective population was collected for which height and weight was recorded, no tooth impactions were present, and occlusion class was based on full cusp malocclusion only. Additionally, it would be interested to blind the study to whether or not the subject had obstructive sleep apnea or not. The clinical relevance for the size of the posterior lies in its importance in identifying obstructive sleep apnea. An ideal sample would consists of a larger sample with the items identified above as a control and with a second group that had obstructive respiratory problems to see if molar occlusion could be used as clinical indicator.

CHAPTER 5
CONCLUSION

Molar occlusion by itself is not a sufficient indicator of airway volume, airway area or minimum axial area. Our findings do not necessarily contradict the existing literature, but do not actively support it either. Further research with additional variables and a larger, homogenous sample size might lead to a better predictive model with regard to the relationships between occlusion and the posterior airway. Early diagnosis of different skeletal patterns and their impact on posterior airway anatomy can be paramount in helping a child resume obtain normal skeletal structure before the growth potential is lost. Additionally, early detection of obstructive sleep apnea, resulting from obstruction of the posterior can result in effective treatment modalities before the diseases co-morbidities can manifest.

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BIOGRAPHICAL SKETCH

Evan G. Rubensteen was born in South Florida and raised in Hollywood, Florida. He graduated from MAST Academy in 2001 and NYU with honors in 2005, where he majored in political science and religious studies and minored in chemistry. He then moved to Boston, Massachusetts, where he received his D.M.D. degree from the Harvard School of Dental Medicine. He is expected to receive a Master of Science in dental sciences as well as a Certificate in Orthodontics from the University of Florida in the spring of 2012.

Evan plans on moving back to South Florida after graduation to begin his orthodontic career.