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3-D Upper Airway Comparison between Class I and Class II Adults with Excessive Daytime Sleepiness

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3-D UPPER AIRWAY COMPARISON BETWEEN CLASS I AND CLASS II ADULTS WITH EXCESSIVE DAYTIME SLEEPINESS

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Abstract

Objective: The aim of the study is to determine whether there is a relationship between the risk for daytime sleepiness in adults with Class I and Class II malocclusion and the airway volume, minimum cross-sectional area, and shape at the minimum cross sectional area.

Introduction: Sleep disordered breathing (SDB) is a category of conditions defined by airway complications while a person is sleeping. Obstructive sleep apnea (OSA) is the most common of these disorders and is defined as the presence of repeated episodes of complete or partial airway obstruction, which may be associated with loud snoring and daytime sleepiness. Daytime sleepiness has been identified in 50% of obstructive sleep apnea patients. Prevalence of OSA in the adult population suggests that 9% of females and 24% of males are affected. Some of the risk factors for OSA in adults include obesity, age, and nasal blockage. Mandibular retrognathism and obesity are the major risk factors for OSA. In addition, the neck circumference is a confirmed risk factor for OSA in patients.

OSA treatment includes CPAP (Continuous positive air pressure) which is considered the gold standard for treatment. Other treatments include oral appliances and in some cases, orthognathic surgery for mandibular advancement.

Materials and Methods: This retrospective study included 87 patients 18-60 years of age. The patient's skeletal classification was determined using the Dolphin imaging software. Patients were classified into either skeletal class I or class II based on ANB and Wits values. ANB angle of 0° to 5° is considered class I and ANB angle of >5° is considered class II. The patient's risk for daytime sleepiness was identified using the Epworth Sleepiness Scale. A score of 11 or greater in the Epworth Sleepiness Scale indicates a high possibility of excessive daytime

sleepiness. A score of less than 11 indicates a low possibility of excessive daytime sleepiness. Then Anatomage's InVivo software was used to measure the total airway volume, minimum cross-sectional area, and shape of the airway at the minimum cross-sectional area.

Results: There were significant interactions in the total airway volume ($p<0.001$) and minimum cross-sectional area ($p<0.001$) between skeletal classification and risk for daytime sleepiness. The mean difference in airway volume was greater between high risk and low risk in skeletal Class I (MD=17), while the mean difference in airway volume was much less apparent between high and low risk with skeletal Class II (MD=0.4). The mean difference in minimum cross-sectional area was also greater between high and low risk patients in Class I (MD=51), while the mean difference in minimum cross-sectional area was much less apparent in Class II (MD=3). There were no significant differences in the total airway volume or minimum cross-sectional area between high risk vs. low risk patients ($p=0.18$, $p=0.45$) or between Skeletal Class I vs. Class II ($p=0.59$, $p=0.62$). There were no significant differences or interaction in cross section shape between the skeletal Class I and Class II in high risk vs. low risk patients ($p=0.06$). No significant difference and no significant interaction in gender was found ($p= 0.55$, $p=0.60$).

Conclusions: Skeletal classification and risk have significant impact on airway volume and minimum cross-sectional area, but they do not have an impact on cross section shape. Patients with skeletal Class II have a smaller mean difference in airway volume and minimum cross-sectional area than patients who are skeletal Class I in high risk vs. low risk.

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Chapter 1 : Introduction

Sleep disordered breathing (SDB) is a category of conditions defined by airway complications while a person is sleeping. Obstructive sleep apnea (OSA) is the most common of these disorders and is defined as the presence of repeated episodes of complete or partial airway obstruction, which may be associated with snoring and daytime sleepiness (Slater & Steier, 2012). OSA affects both adult and pediatric populations. Prevalence of OSA in the adult population suggests that 9% of females and 24% of males are affected (T Young et al., 1993). In pediatric populations, the prevalence of OSA has been estimated to be 0.7% to 10.3% (Huynh, Morton, Rompré, Papadakis, & Remise, 2011). While there are similar risk factors, there tends to be different emphasis on certain ones among children and adults in OSA. In adults, obesity has been predominately associated with OSA. In children, adenotonsillar hypertrophy, allergies, frequent colds, and morphologic features related to dolichofacial appearance are primarily associated with sleep-disordered breathing (Huynh et al., 2011). In addition, the neck circumference is a confirmed risk factor for OSA in patients (Terry Young, 2002). Mandibular retrognathism is also considered a major risk factor along with obesity for OSA (Arens & Marcus, 2004; Dempsey, Veasey, Morgan, & O'Donnell, 2010). In mandibular retrognathism, there is decreased mandibular length and an increased overbite (Silva, Lacerda, Silva, & Ramos, 2015). Retruded mandibles are often associated with class II malocclusions. Studies have shown that airway volumes tend to be lower in class II malocclusions (El & Palomo, 2011). Upper airway length (UAL) has been used to indicate the presence and severity in class II malocclusions. Having a longer upper

airway relates to the presence and severity of OSA (Susarla, Abramson, Dodson, & Kaban, 2010). The vertical dimension also plays a role in affecting pharyngeal airway. In class II malocclusions, those with a higher mandibular angle tend to have a smaller airway space (Wang et al., 2014). Some additional risk factors for OSA in adults include age and nasal blockage (Hussain, Cloonan, Islam, & Rahbar, 2010).

Severity of obstructive sleep apnea is determined by the Apnea/Hypopnea Index AHI where mild OSA is AHI >5, moderate OSA with AHI >15, Severe OSA with AHI > 30 (Gilles, L., Cistulli, P., Smith, 2009) . Some of the health effects of OSA in adults include: Co-morbid hypertension, arrhythmias, bi-directional relation of OSA with type II diabetes mellitus (Fletcher, DeBehnke, Lovoi, & Gorin, 1985). 15-30% of patients with OSA have been found to have type II diabetes (Kent et al., 2014; Pamidi & Tasali, 2012).

The Gold standard for diagnosing SDB is the overnight polysomnogram (PSG) (Ferber et al., 1994). Due to the cost of administering the polysomnogram and cost of expertise to conduct the study as well as time spent in the study, other alternatives have been suggested such as the off-line automated oxygen pulse oximetry, home sleep tests, and screening questionnaires. The Epworth sleepiness scale questionnaire has a high reliability in testing- and retesting as well as an internal consistency (Johns, 1992). This scale measures the patient's daytime sleepiness which is one of the most common symptoms of obstructive sleep apnea. Another questionnaire is the STOP (*s*noring, *t*iredness, *o*bserved apnea and high blood *p*ressure) –BANG (*B*MI, *a*ge, *n*eck circumference, *g*ender). The STOP-BANG questionnaire screens patients for risk of sleep disordered breathing and has a sensitivity of 90% (Chung et al., 2012).

The gold standard for OSA treatment is the CPAP (continuous positive air pressure) machine (Gay, Weaver, Loube, & Iber, 2006; Weaver et al., 2012). Other treatments include oral appliances and orthognathic surgery both of which are for mandibular advancement. Surgical advancements of the maxilla and mandible increase the velopharynx by elevating soft tissue connected to the maxillofacial complex (Fairburn et al., 2007). However, surgery is invasive and costly; therefore, less invasive alternatives are sought. A non-invasive option is an oral appliance that anteriorly positions the mandible, which has been shown to increase the airway but with a large variability among patients (Gale et al., 2000).

A study utilizing cephalometric analysis of patient in a supine position will show airway constriction with increases in tongue volume and increased soft palate thickness compared to upright position (Pae et al., 1994). However, imaging in the supine position alone excludes the important physiologic factors of being in the neurologic state of sleep and its regulatory mechanisms of breathing (Dempsey et al., 2010). Furthermore, two-dimensional analysis of a three-dimensional structure also has certain limitations and drawbacks. Therefore, three-dimensional technology such as CBCT has been an important supplement in the diagnosis and evaluation of airway problems and a strong correlation exists between CBCT measurements and lateral cephalograms (Bronoosh & Khojastepour, 2015). Both 2-D and 3-D analyses have evaluated airway volume in skeletal malocclusions and have shown reduced airway in class II malocclusions (Castro-Silva et al., 2015; de Freitas, Alcazar, Janson, de Freitas, & Henriques, 2006; Grauer, Cevidanes, Styner, Ackerman, & Proffit, 2009; Lowe et al., 1996). Three-dimensional

analyses such as MRI and CBCT have supported the decrease in airway for OSA patients (Ogawa, Enciso, Shintaku, & Clark, 2007; Richard J. Schwab et al., 2003). Although three-dimensional analyses have been utilized to evaluate upper airway volume in patients with skeletal Class I, II, and III, they are without consideration of the patients' risk or diagnosis for sleep disordered breathing or its risk factors. There are several 3-D analysis software packages available including Dolphin, InVivo and others. Weissheimer et al (2012) showed in his study that all of the commonly used 3-D analysis software packages are reliable and accurate in measuring the volume.

The purpose of this retrospective study is to utilize 3-D imaging to execute measurements in patients with skeletal Class I and II characteristics and evaluate findings to determine whether there is a difference in the airway volume, minimum cross-sectional area and shape of the airway at the minimum cross-sectional area between the high risk and low risk group for excessive daytime sleepiness. The information and knowledge gained from this research project will allow orthodontists to provide care to the patient in a holistic fashion. The results of this study will contribute to the current knowledge about the relationship between the airway and one of the most common symptoms of sleep apnea, excessive daytime sleepiness (EDS).

Research Questions

Research Question 1: What is the impact of level of risk (high vs. low) and Class I malocclusion classification on airway volume produced?

This question produced three hypotheses.

Hypothesis1.1. There is a significant difference in airway volume between patients classified as high risk for excessive daytime sleepiness (EDS) versus patients classified as low risk for EDS.

Hypothesis1.2. There is a significant difference in airway volume between patients classified as Class I malocclusion versus Class II malocclusion.

Hypothesis1.3. There is a significant difference in airway volume between patients classified as high risk for excessive daytime sleepiness (EDS) versus patients classified as low risk for EDS and patients diagnosed with Class I vs. Class II malocclusions.

Research Question 2: What is the effect of the measured minimum cross sectional area of the airway between levels of risk (high vs. low) among malocclusion classifications (Class I)?

Hypothesis2.1. There is a significant difference between the measured minimum cross sectional areas of the airway in patients classified as high risk for excessive daytime sleepiness (EDS) versus patients classified as low risk for EDS.

Hypothesis2.2. There is a significant difference between the measured minimum cross sectional areas of the airway in patients classified as Class I malocclusion versus Class II malocclusion.

Hypothesis2.3. There is a significant difference between the measured minimum cross sectional areas of the airway in patients classified as excessive daytime sleepiness (EDS) versus patients classified as low risk for EDS and in patients diagnosed with Class I vs. Class II malocclusions.

Research Question 3: What is the effect of the measured minimum cross sectional area shape between the level of risk (high vs. low) and malocclusion classification (Class I)?

Hypothesis3.1. There is a significant difference between the measured minimum cross sectional area shape of the airway in patients classified as high risk for excessive daytime sleepiness (EDS) versus patients classified as low risk for EDS.

Hypothesis3.2. There is a significant difference between the measured minimum cross sectional area shape of the airway in patients classified as Class I malocclusion versus Class II malocclusion.

Hypothesis3.3. There is a significant difference between the measured minimum cross sectional area shape of the airway in patients classified as high risk for excessive daytime sleepiness (EDS) versus patients classified as low risk for EDS and in patients diagnosed with Class I vs. Class II malocclusions.

Chapter 2 : Literature Review

Obstructive Sleep Apnea

Sleep apnea is a potentially serious and chronic sleep disorder in which breathing repeatedly interrupted. Three types of apnea have been distinguished: central, obstructive, and mixed. Central sleep apnea occurs when the brain temporarily fails to send a signal to the muscles responsible for controlling breathing. Obstructive sleep apnea is caused by a partial or complete obstruction of the airway. Mixed sleep apnea or complex sleep apnea is a combination of central sleep apnea and obstructive sleep apnea.

Obstructive sleep apnea (OSA) is the most common type of sleep disordered breathing. OSA involves a decrease or complete pause in airflow despite a continuous effort to breathe (Arnold et al., 2017). It is characterized by repetitive episodes of shallow or interrupted breathing during sleep, and is usually associated with an oxygen reduction in the blood. These episodes of decreased breathing, called apneas, typically last 20 to 40 seconds but must last for at least 10 seconds to be considered an apneic event (Eckert & Malhotra, 2008; Mbata & Chukwuka, 2012). A noticeable sign of OSA is snoring. It affects people of all ages, gender, and races. The prevalence of obstructive sleep apnea is 24% in men and 9% in women within the middle-aged population (T Young et al., 1993). As age increases, the prevalence also rises and is estimated to be around 28%–67% for elderly men and 20%–54% for elderly women (Goodday, 1997). Risk factors for OSA include obesity, larger neck circumference, anatomical obstructions such as large tonsils, or anatomical abnormalities.

Complications of having this chronic disease can include heart disease, hypertension, cognitive impairment, high BMI, tiredness, poor work performance, diabetes, and higher

mortality rate (Punjabi, 2008). The health consequences of OSA are numerous although the causal relationships may not be well elicited. The sequelae of OSA in adults includes excessive daytime sleepiness, diminished awareness during the day, and increased chance of automobile and other accidents. It can also lead to a higher risk for postoperative cardiac and respiratory complications (Qaseem et al., 2014). Obstructive sleep apnea is becoming more recognized as a significant cause of medical morbidity and mortality (Punjabi, 2008).

Classification of OSA involves the apnea-hypopnea index (AHI). Mild OSA (AHI of 5–15) describes involuntary sleepiness at times of activities that requires little attention. These symptoms may cause minor difficulties with work or social activities. Moderate OSA (AHI of 15–30) describes involuntary sleepiness during activities that need some attention. These symptoms may cause moderate difficulties with work or social functioning. Finally, severe OSA (AHI of >30) describes involuntary sleepiness during activities that demands more attention (Arnold et al., 2017). These symptoms can cause more serious problems with a career and social life.

Pathophysiology

The upper airway is an intricate structure required to perform various activities such as swallowing, vocalization, and respiration. The patency of the pharyngeal structures is critical to the ventilation function. The most common sites of airway collapse in OSA are within the oral pharyngeal region. The most common being the retropalatal region of the oropharynx (Dempsey et al., 2010). In most patients with OSA, there are little or no problems with breathing or airway patency during wakefulness. Normally, in the wakeful state, the muscles of the pharynx are more contracted and rigid maintaining the form of the airway and keeping the airway patent. However,

during sleep, gravity and other biophysiological aspects comes into consideration. In the sleep state, the pharyngeal muscles no longer have the neurological triggers that allow them to keep their tensed form causing the pharyngeal wall to collapse. Additionally, the supine position permits for a gravitational pull to the tongue more posteriorly reducing the airway lumen (McCrillis, Haskell, Brammer, & Chenin, 2009). Consequently, when air flows through this narrowed lumen, it causes the flaccid pharyngeal walls and other soft tissues to vibrate and tremble which manifests as snoring. As the lumen becomes more constricted, the airflow increases to a faster velocity. Eventually, the intraluminal pressure is decreased until it leads to an impeded airway, causing a cessation of breathing. The pause in air flow leads to a drop in oxygen triggering the individual to wake up. As the individual subconsciously wakes up breathlessly, the pharyngeal muscles regain their structure allowing the airway lumen to become unobstructed (McCrillis et al., 2009). Subsequently, air flow is increased and becomes more normal allowing the individual to fall asleep again. The apneic process is cyclical and can occur from a few to many times in one night.

In summary, during the wakeful state, there is a compensatory neuronal trigger of dilator muscles that provides support to the anatomically compromised and collapsible pharynx. The muscle tone of the upper airway is almost completely weakened during sleep which causes the airway to collapse or narrow. The process of repeated apneas involves multiple neurophysiological processes that are markedly different and vary among individuals (Dempsey et al., 2010).

Epidemiology of Adult Obstructive Sleep Apnea

Obstructive sleep apnea is a common condition. It affects about 9% of men and 4% of women. There is a male predilection with a risk that is two- to three-fold higher for men compared to women (Terry Young, Peppard, & Gottlieb, 2002). OSA affects all ages. However, the risk of OSA does increase with age. The prevalence of OSA in certain populations such as elderly patients, hypertensive patients, and patients with heart disease are higher (Al Lawati, Patel, & Ayas, 2009). There are a number of risk factors for OSA including obesity, male sex, and a genetic component. There are also studies that show the African American population has a higher prevalence of OSA when compared with Caucasians. Up to 5% of adults in Western countries are likely to have undiagnosed OSA syndrome which can lead to unknown complications and medical implications (Terry Young et al., 2002)

Diagnosis

The gold standard for diagnosing OSA is with an overnight polysomnography (PSG). Polysomnography is a sleep study that records comprehensive biophysiological changes that occur during sleep. Full night PSG is recommended for the diagnosis of OSA. In a PSG, OSA is confirmed when the number of apneic events is greater than 15/hour or greater than 5/hour with excessive daytime sleepiness or at least two of the following symptoms: Choking, recurrent awakening from sleep, feeling unrefreshed after sleeping, daytime fatigue, or impaired concentration (Gilles, L., Cistulli, P., Smith, 2009). Patients also report unintended sleep episodes during wakefulness, excessive daytime sleepiness, weariness, waking up breathlessly, loud snoring, and breathing disruptions (Epstein et al., 2009). The snoring and breathing interruption leads to sleep interruptions and therefore, excessive daytime sleepiness occurs as a

result (Bonsignore, 2017). Also the severity of OSA can be determined using this overnight sleep study by determining the frequency of apneas and hypopneas during the sleep cycle. The frequency of obstructive events is reported as an apnea/ hypopnea index (AHI) and a greater number indicates a greater severity of sleep apnea (Epstein et al., 2009).

A patient's health history and physical examination also provide important adjunctive diagnostic information. A comprehensive sleep evaluation as part of routine health history, part of evaluation of symptoms of OSA, or part of comprehensive evaluation of high risk patients further provides necessary information. Hallmarks of OSA include snoring and daytime sleepiness. Daytime sleepiness can be assessed using the Epworth Sleepiness Scale. Also an evaluation for the presence of obesity, retrognathia, increased neck circumference, body mass index, and hypertension should also be taken into consideration ((Epstein et al., 2009).

Relationship of Craniofacial Patterns to OSA

In obstructive sleep apnea, a narrowing or reduction of the pharyngeal airway is seen. The decrease in airway size can lead to occurrences of apneas and hypopneas. In a CT study done by Bohlman et al. (1983), the airway was significantly narrowed in all the OSA patients while no narrowing was seen for the control group. There are many craniofacial and anatomic factors that can influence the anatomy and function of the upper airway. An association has been seen between skeletal malocclusions and airway. With a retrognathic mandible, the posterior position of the mandible decreases the airway size. Retrognathic mandibles are associated with a smaller pharyngeal airway than normal mandibles. It has also been found that Class II malocclusions were significantly more common in the OSA group (Banabilh, 2017).

Cephalometric studies have shown that hyperdivergent patients have a narrower airway in the anteroposterior dimension than normodivergent patients (Joseph, Elbaum, Cisneros, & Eisig, 1998). The tongue was also positioned more inferiorly and posteriorly in hyperdivergent patients obstructing the airway. In patients with a vertical growth pattern, the upper airway is more narrowed in dental Class I and Class II malocclusions when compared to patients with normal growth patterns (de Freitas et al., 2006).

Airway Assessment

Airway assessment is an important part in the diagnosis, treatment, and management of the airway problems in OSA. Methods of airway evaluation involve studying physiologic and morphometric aspects of the airway. Physiologic studies include overnight polysomnograms to evaluate air flow, brain activity and other biophysiological changes. Morphometric aspects that are studied include airway volume, minimum cross-sectional area, airway shape, width and length. Radiographic evaluation has been a commonly used method for airway assessment. Lateral cephalometric studies have been used to evaluate various aspects of the airway such as the size of the tongue, soft palate, positions of the hyoid bone, dimension of the upper airway lengths, mandibular length, and maxillary length (Gungor, Turkkahraman, Yilmaz, & Yariktas, 2013; Guttal, Kruthika S ; Burde, 2013). The limitation of a lateral cephalogram is that it provides a 2-dimensional image of a complex 3-dimensional structure. In contrast, computerized tomography (CT) and magnetic resonance imaging (MRI) are able to provide a more holistic representation of the upper airway. With CT and MRI, patients are positioned in a supine position which resembles the sleeping position (Fleck et al., 2017). Therefore, the images give a better depiction and positions of the anatomical structures due to gravity. However, CT and MRI

are more expensive, more complex to maneuver, less accessible, and subject patient to higher radiation compared to lateral cephalograms.

In orthodontics, panoramic and lateral cephalogram radiographs have been conventional radiographs used to aid in diagnosis and treatment planning of orthodontic care. However, due to the limitations of the 2-dimensional views of panoramic radiographs and cephalograms, cone-beam computed tomography (3-dimensional) has emerged as a comprehensive imaging modality with further practical applications. In addition to being able to examine structures from more views, volumes and anatomic structure sizes can be computed (Mah, Huang, & Choo, 2010; Veys et al., 2017).

Epworth Sleepiness Scale

Excessive daytime sleepiness is a cardinal feature of the OSA syndrome. Excessive daytime sleepiness is regarded as the most common and most important symptom of OSA. There are several questionnaires that have been used to screen for sleep apnea and daytime sleepiness. Questionnaires include STOP, STOP-BANG, and the Epworth Sleepiness Scale (ESS) for excessive daytime sleepiness.

The Epworth Sleepiness Scale is a self-administrated questionnaire that is a subjective measure of a patient's sleepiness and used to assess daytime sleepiness. It is a commonly accepted method used to assess a person’s level of typical sleepiness during the day. The test asks subjects to rate the tendency to become sleepy in eight situations. The scale is rated from 0–3 (0 = would never dose, 1 = slight chance of dozing, 2 = moderate chance of dozing, and 3 = high chance of dozing). The total ESS score is the addition of the ratings and can range between 0 and 24. A higher score indicates a higher risk of daytime sleepiness. Normal is from

0–10 and excessive daytime sleepiness is considered 11–24. Thus, the ESS final score was categorized into low risk for sleepiness as less than 11 and high risk for sleepiness as greater than or equal to 11 (El-Sayed, 2012). The ESS score is closely associated to the frequency of apneas (Johns, 1991). A direct relationship between ESS and AHI has been reported establishing ESS as a possible clinical predictor as well as a good screening method for the identification of patients with OSA (Santaolalla Montoya et al., 2007). In a previous study, a statistically significant relationship between apnea severity and ESS has been concluded (Gottlieb et al., 1999).

Risk Factors of Obstructive Sleep Apnea

Obesity is considered a major risk factor for OSA and can be measured by body mass index (BMI). Patients with OSA generally have a higher BMI. Another measure of obesity is neck circumference. Increased neck circumference of greater than 16 inches in women and greater than 17 inches in men suggests the increased risk of OSA (Epstein et al., 2009). Obesity potentially increases risk of OSA by increasing fat depositions in the tissues of the upper airway which reduces the airway lumen (Al Lawati et al., 2009). Obese people with a larger neck circumference also tend to have larger tongues and soft palate (Ferguson, Ono, Lowe, Ryan, & Fleetham, 1995).

Gender is another risk factor in patients for OSA. Males have approximately twice the risk of developing OSA compared to women. Males typically have a higher fat distribution in the upper body versus a lower body fat distribution for women. Therefore, there is an increased chance of greater fat depositions in the neck area which can affect the airway passage. Postmenopausal women have a higher risk of OSA compared to premenopausal women after

controlling for BMI, age, or other risk factors indicating that female hormone changes may play a role in developing OSA (Al Lawati et al., 2009).

Ethnicity is also a factor in determining risk for OSA. Asians and African Americans tend to have an increased risk compared to Caucasians. While obesity plays a greater role in OSA risk for African Americans, anatomic features such as a smaller cranial base angle and smaller thyromental distance contributes to the increased risk in Asians (Al Lawati et al., 2009).

Craniofacial anatomy also plays a significant role in OSA. The anatomy of soft and hard tissues can alter the structural properties of the upper airway and increase its tendency to collapse during sleep. Abnormalities in anatomy can also cause obstructions to the airway (Punjabi, 2008).

Other risk factors include family history, genetics, tobacco use, and alcohol consumption. There are studies that show inheritance and familial factors in obstructive sleep apnea. The susceptibility to OSA has been linked to frequency of affected relatives. Smoking has been thought to cause inflammation to the pharyngeal walls thus narrowing the airway. Alcohol is assumed to affect certain regulatory mechanisms during inspiration and expiration (Punjabi, 2008).

Treatments

A range of treatments exists for obstructive sleep apnea from minimally invasive procedures to more invasive surgical techniques. Non-surgical treatments consist of pharmacological agents, weight loss, oral appliances, and continuous positive airway pressure (CPAP). Pharmacological treatments have included tricyclic anti-depressants, serotonergic

agents, sex steroids, theophylline and anti-hypertensive agents (Grunstein, Hedner, & Grote, 2001). Weight reduction has been seen to reduce the airway collapsibility, the lateral pharyngeal wall thickness and the size of the fat pads (R. J. Schwab et al., 1995). Another treatment approach is using oral devices such as mandibular advancement devices and tongue retaining devices. Mandibular advancing appliances cover the maxillary and mandibular dentition and hold the mandible in a forward position therefore opening the airway. Relative contraindications include temporomandibular joint (TMJ) disorders or pain because the dental appliance postures the mandible forward and can add stress to the TMJ. Similarly, tongue retaining devices posture the tongue anteriorly in order to increase the airway volume (Epstein et al., 2009).

CPAP is the most commonly used method to treat OSA and is the gold standard for treatment of OSA in adults. This treatment consists of a machine that delivers constant positive air pressure during respiration to support upper airway patency during sleep through a mask to the patient (Gharibeh & Mehra, 2010). The anatomical advantages of CPAP are forward repositioning of the tongue and soft palate in addition to expansion of the airway with positive airway pressure (R. J. Schwab & Goldberg, 1998). Treatment with CPAP has positive results and shown to reduce AHI as well as improve daytime sleepiness; however, it relies on patient's compliance. Patients usually discontinue use of the CPAP due to mouth dryness, skin irritation, air leakage, and claustrophobia (Gharibeh & Mehra, 2010).

In situations where non-surgical techniques have not been successful or patients are intolerable of devices, surgical interventions are considered. Surgical interventions usually involve reconstructing or bypassing the upper airway. Common surgeries include nasal surgery, tracheostomy, uvulopalatopharyngoplasty (UPPP), and maxillomandibular advancement. Nasal

surgeries include removal or reduction of nasal structures or correction of the nasal septum. In tracheostomy, you can create a new air passageway by inserting a metal or plastic tube through which the patient breathes. In UPPP, the soft palate, some or all of uvula, tonsils, and adenoids tissue are usually removed (Arnold et al., 2017). Maxillomandibular advancement is successful in treating OSA patients with craniofacial problems (R. J. Schwab & Goldberg, 1998). The surgical advancement enlarges the space behind the tongue and soft palate.

Chapter 3 : Material and Methods

SUBJECTS

A total of 87 pre-treatment orthodontic patient records were obtained from the UNLV School of Dental Medicine Orthodontic Department's archival dental records from July 2012- June 2016. The sample consists of individuals ranging from 18-60 years. The pre-treatment orthodontic records include: lateral cephalometric radiograph, CBCT scan, and an Epworth Sleepiness Scale.

Exclusion criteria included:

1. Patients with syndromes documented to have higher risk for sleep disordered breathing
2. Patients with craniofacial anomalies
3. Patients with chronic allergies
4. Patients on muscle relaxants
5. Patients with current respiratory infections
6. Dolichocephalic patients
7. Skeletal Class III patients
8. Unacceptable image quality

Information was de-identified by UNLV SDM personnel. A UNLV Institutional Review Board approval for use of archival dental records was approved (Protocol #837924, Appendix A). Dolphin Imaging (Chatsworth, CA), Invivo5 (Anatomage, San Jose, CA) and axiUm (Henry Schein, Melville, NY) soft wares are needed to access and analyze existing patient information. Epworth Sleepiness Scale was used to identify patients' probability of excessive daytime

sleepiness which indicates risk for sleep disordered breathing. Dolphin imaging was used to determine the patients' skeletal classification. InVivo was used to measure the airway volume, minimum cross- sectional area and shape. The axiUm database was used to collect anthropometric measurements such as age, gender, BMI, and neck circumference. Data was recorded in Excel 2010 (Microsoft, Redmond, WA).

SUBJECT GROUPS

Individuals were categorized into a high risk category and a low risk category and further subdivided into Class I and Class II skeletal malocclusion within each risk group. The Invivo5 Software was used to determine the:

1. Airway volume
2. Minimum cross-sectional area
3. Shape of airway at the minimum cross-sectional area.

ASSESSMENT OF DAYTIME SLEEPINESS

A score of 11 or greater in the Epworth Sleepiness Questionnaire (Appendices B and C) indicates a high possibility of excessive daytime sleepiness and therefore, a higher risk for sleep disordered breathing and high risk for OSA. A score of less than 11 indicates a low possibility of excessive daytime sleepiness and lower risk for OSA.

CEPHALOMETRIC MEASUREMENTS

The cephalometric machine (Orthopantomograph OP300, Instrumentarium) was operated at 65Kv, 2.0 mA, and exposure time of 16 seconds. The patient was placed with the midsagittal

plane parallel with the image receptor. The craniostat was placed in the patient's ears in order to help position the patient's head. Imaging was performed with the patient biting in centric occlusion.

The anteroposterior (AP) skeletal class and vertical skeletal classification were determined from lateral cephalometric measurements. Subjects were classified into either skeletal class I or class II based on ANB and Wits values.

ANB - determined by measuring the angle from A point to Nasion to B point (Figure 3-1). ANB angle of 0° to 5° is considered class I and ANB angle of >5° is considered class II.

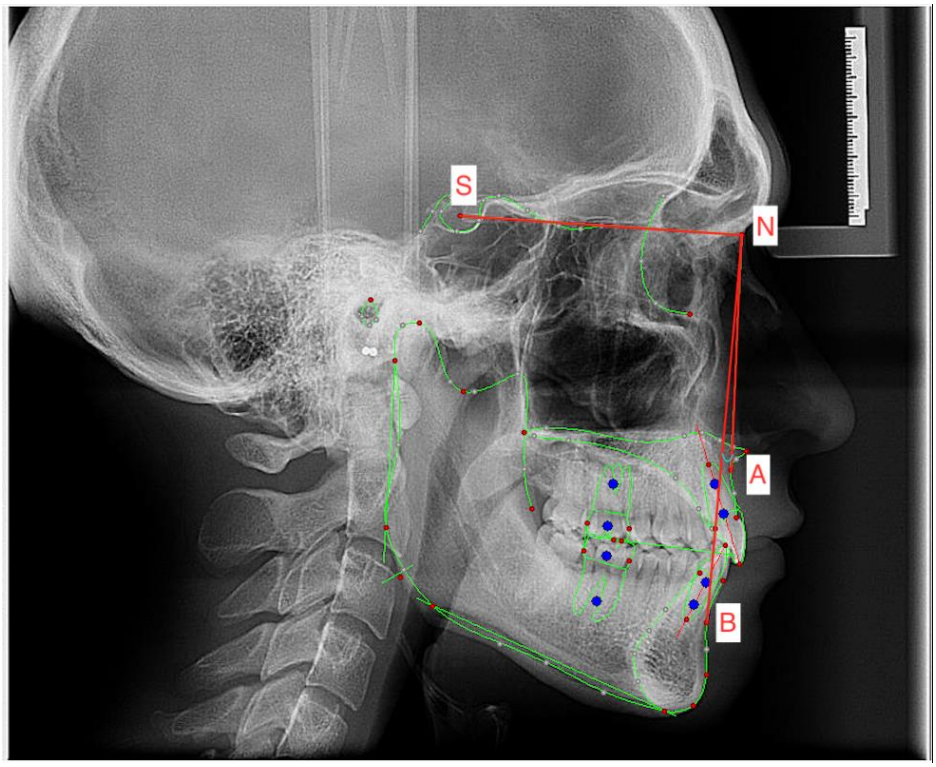

Figure 3-1. ANB measurement (blue angle)

Wits – After drawing perpendicular lines from points A and B onto the occlusal plane, the Wits value is the difference in distance (mm) between points A and B (Figure 3-2). Wits value of 2 to -4 mm is considered class I and >2 mm is considered class II.

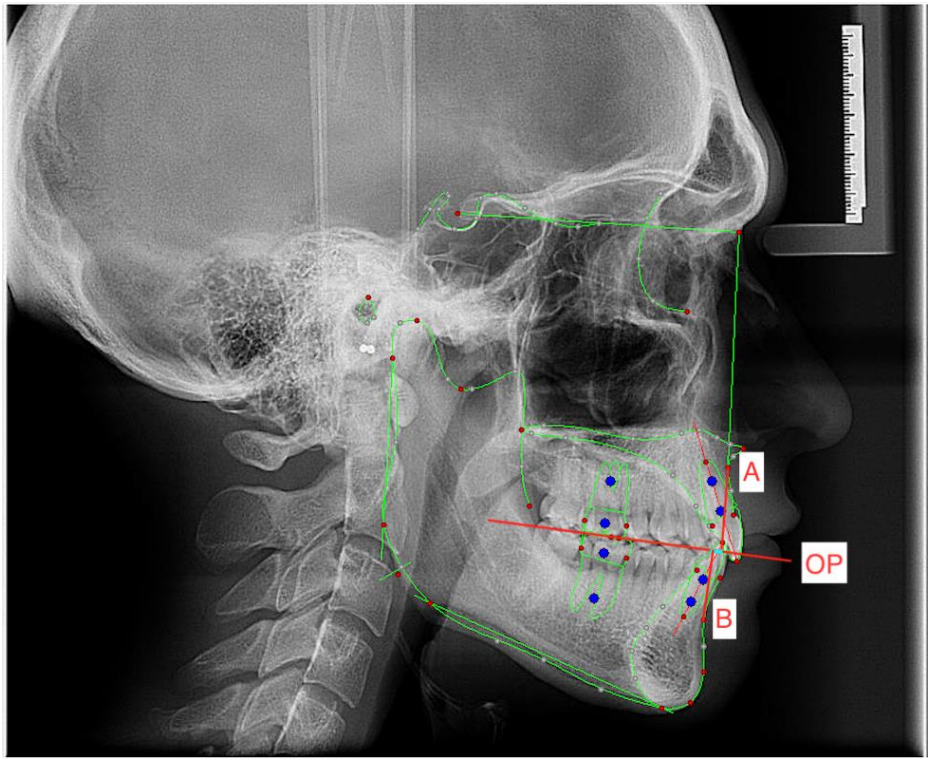

Figure 3-2. WITS measurement (blue line)

Vertical skeletal classification was determined using Frankfort horizontal angle (FMA) and MP-SN values. Subjects with a hyperdivergent skeletal classification were excluded.

FMA - the angle formed by Frankfort Horizontal plane and mandibular plane (Figure 3-3). Hyperdivergent is considered >27°.

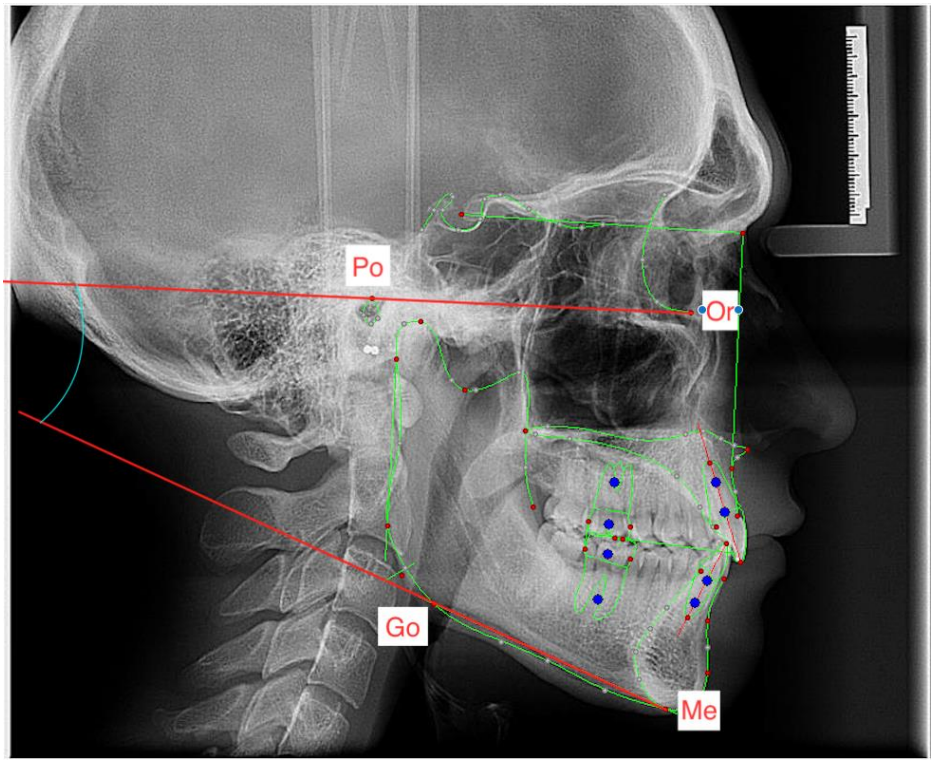

Figure 3-3. FMA (blue angle)

MP-SN - angle formed by the mandibular plane and the line passing through sella-nasion (Figure 3-4). Hyperdivergent is considered if MP-SN angle is >36°.

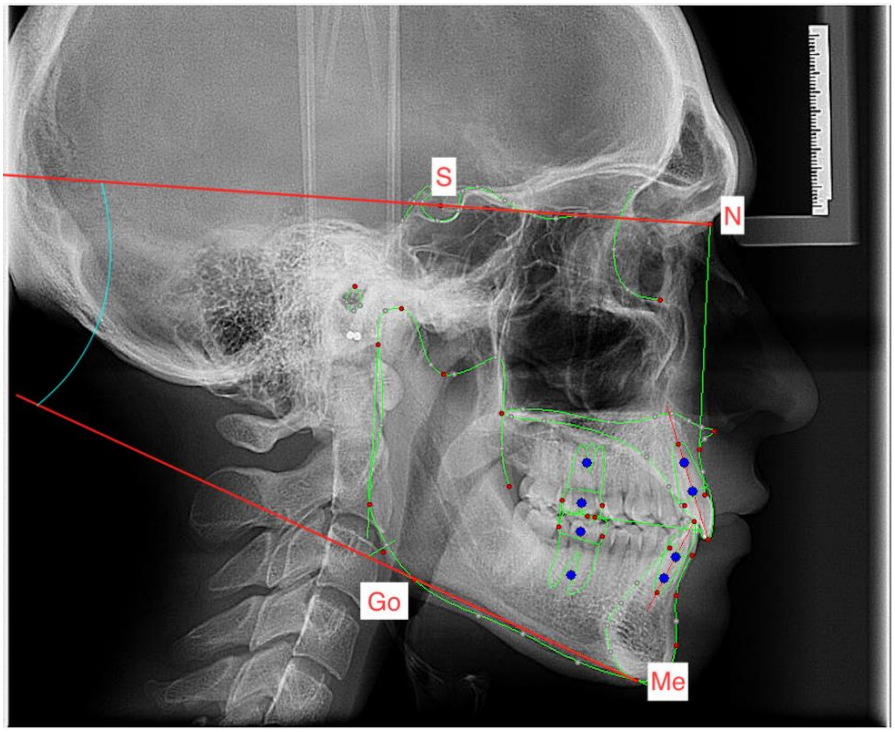

Figure 3-4. MP-SN (blue angle)

CBCT IMAGING PROTOCOL

Images were taken at 120 kV, 15 mA, and with exposure time of 10 seconds using the CBCT machine (CB MercuRay, Hitachi Medical Corp). With the patient seated in the chair, the patient's head was positioned so Frankfort Horizontal Plane is paralleled to the floor. Imaging was performed with the patient biting in centric occlusion. The data were in Digital Imaging and Communications in Medicine (DICOM) format.

OROPHARYNGEAL AIRWAY MEASUREMENTS

Volumetric rendering of the CBCT images were visualized using InVivo5 software. The volumetric region of interest (ROI) was examined in the sagittal view. The upper border was considered to be the plane drawn parallel to the Frankfort Horizontal and going through the most distal point of the hard palate. The lower border was the plane parallel to Frankfort Horizontal

and passing through the most inferior border of the hyoid bone. Once the ROI was established, the airway calculation tool was selected and points were picked along the airway path starting from the upper border to the lower border of the ROI (Figure 3-5a-b). The airway tool automatically rendered the airway volume in cubic centimeters (cc) and the slice with the minimum cross-sectional area (minCSA) in squared millimeters (mm2) with a right click on the mouse button (Figure 3-5c).

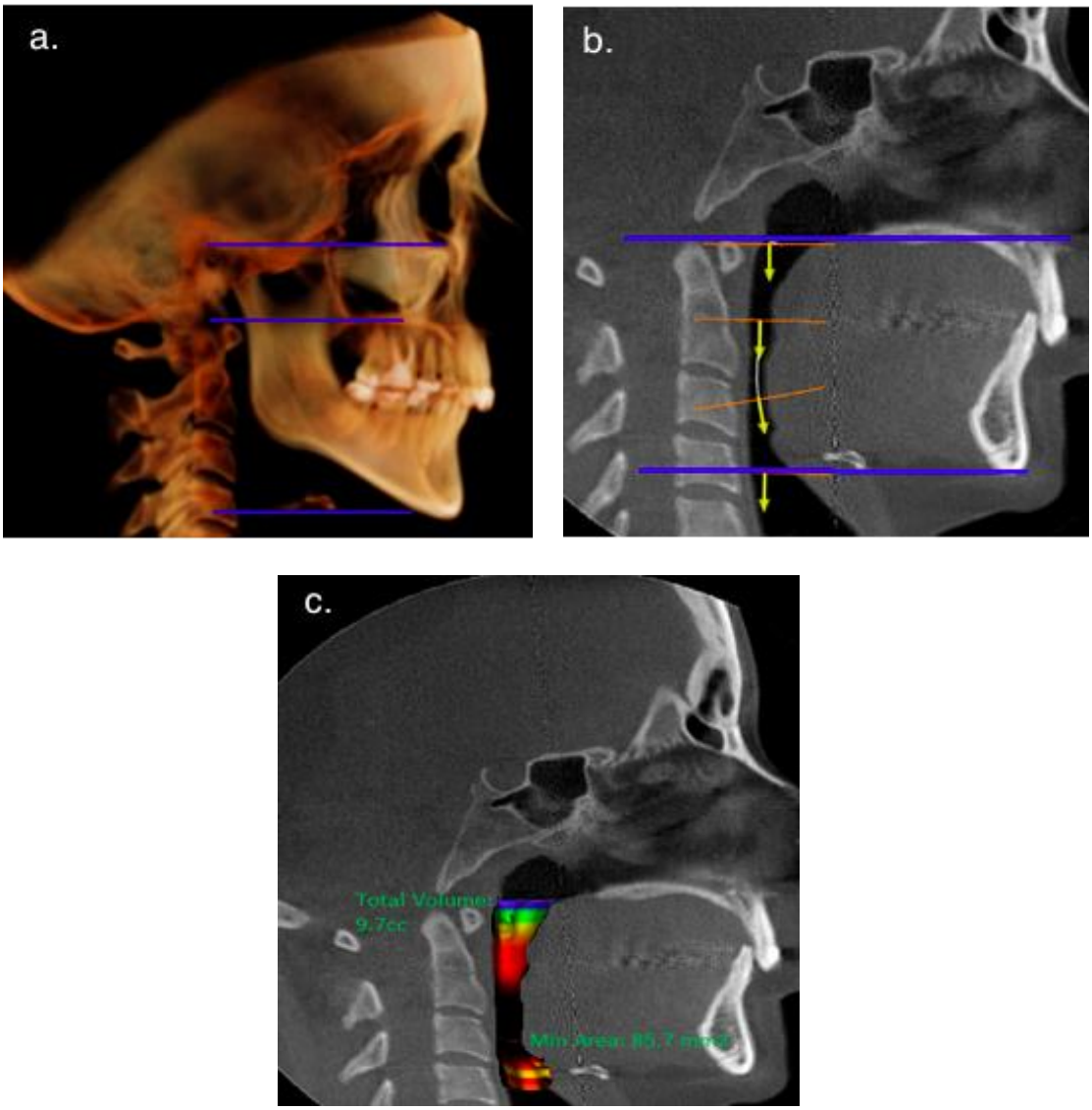

Figure 3-5 Analysis of ROI. a. Upper and lower borders of ROI paralleled to Frankfort

horizontal were established b. Points selected along the air pathway c. Airway volume and minimum cross sectional area slice (red line) along with the minCSA

In order to view the minimum cross-section slice in the axial dimension to evaluate the shape of the airway at its minimum cross sectional area, it was re-oriented by using patient orientation tool (Figure 3-6). The vertical and horizontal lines are then oriented over the minimum cross sectional area lining up the horizontal line with the line of the minimum cross sectional area. An axial view of the minimum cross sectional area is then seen (Figure 3-7). The shape categories used were circular, oval, elliptical, and other. The shapes of the airway were categorized based on measurements along with the observed geometric form. Some of the airway shapes had obstructions or other noticeable irregularities and those were taken into consideration as well.

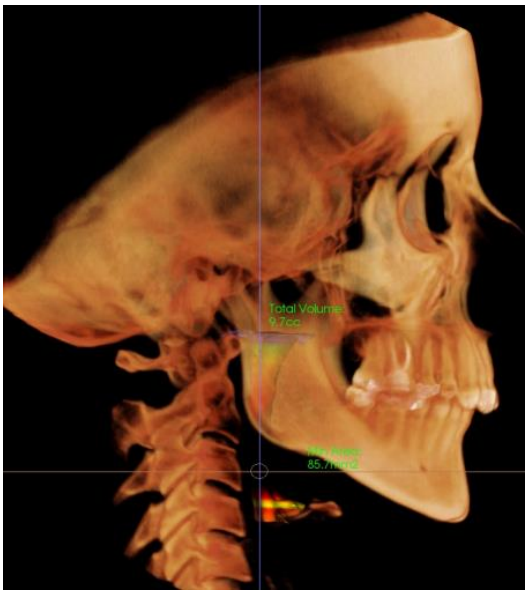

Figure 3-6. Reorientation of the image

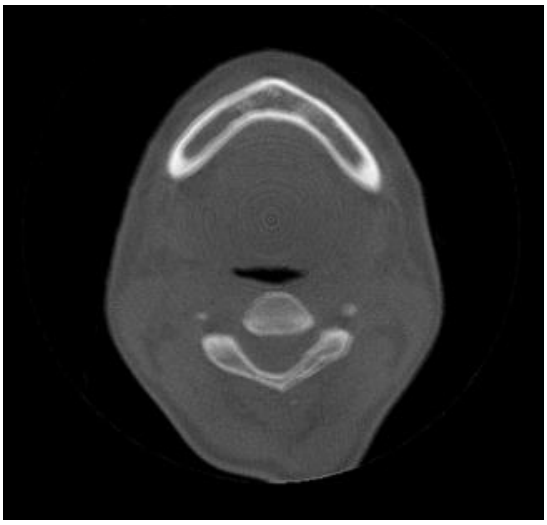

Figure 3-7. Airway shape at the minimum cross-sectional area

STATISTICAL ANALYSIS:

Data will be coded and entered into data worksheets that will be analyzed with SPSS 24.0 (IBM, Inc.). Mean and standard deviation were performed to evaluate relationships among variables. Statistical tests such as Two-tailed, Mann-Whitney U tests, and Two-way Analysis of Variance (ANOVA) were used to evaluate the data with a significance level of $p<0.05$.

Chapter 4 : Results

The sample included 87 patients with 54 females and 33 males.

gender	n
Male	33
Female	54

Table 4-1. Gender Statistics

		n	Total Airway Volume (cm3)	Minimum Cross-Sectional Area (mm2)
Age (years)	<40	75	27.9	209.1
	≥40	12	41.7	191.8

Table 4-2. Age Statistics

	n	Total Airway Volume (cm3)	Minimum Cross-Sectional Area (mm2)
Class I	32	28.1	215.4
Class II	55	30.8	201.6
Low	55	30.3	204.3
High	32	25.5	193.6
Class I Low	19	34.9	236
Class I High	13	18.2	185.2
Class II Low	36	30.9	202.8
Class II High	19	30.5	199.4

Table 4-3. Group Statistics

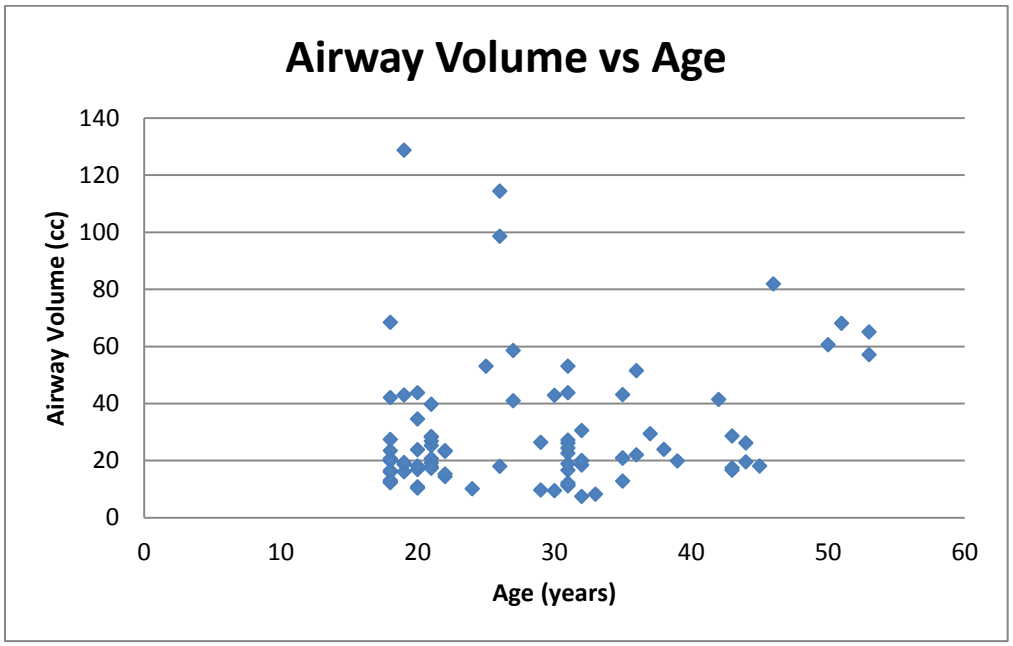

Figure 4-1. Scatterplot of Airway Volume vs Age

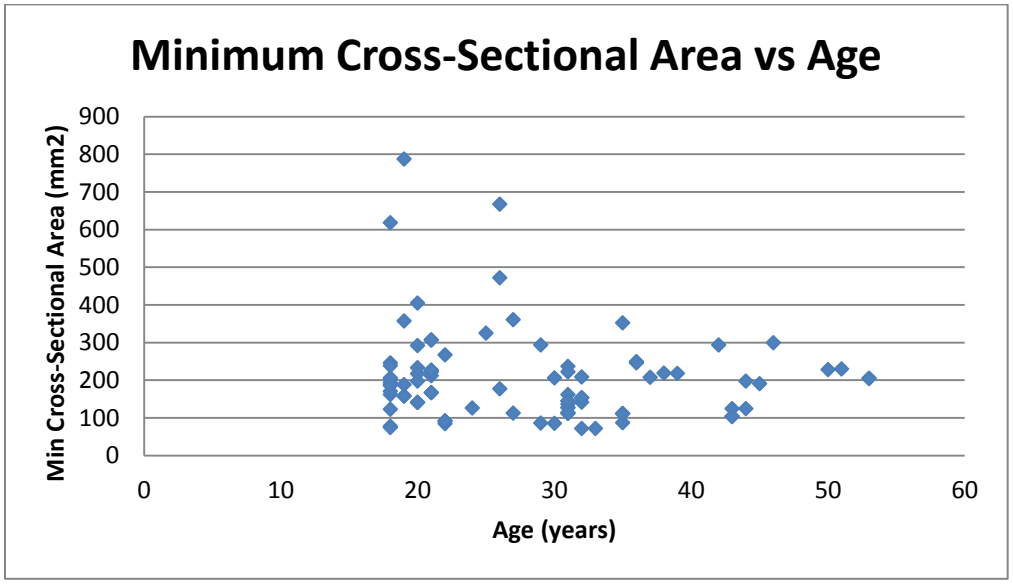

Figure 4-2. Scatterplot of Minimum Cross-Sectional Area vs Age

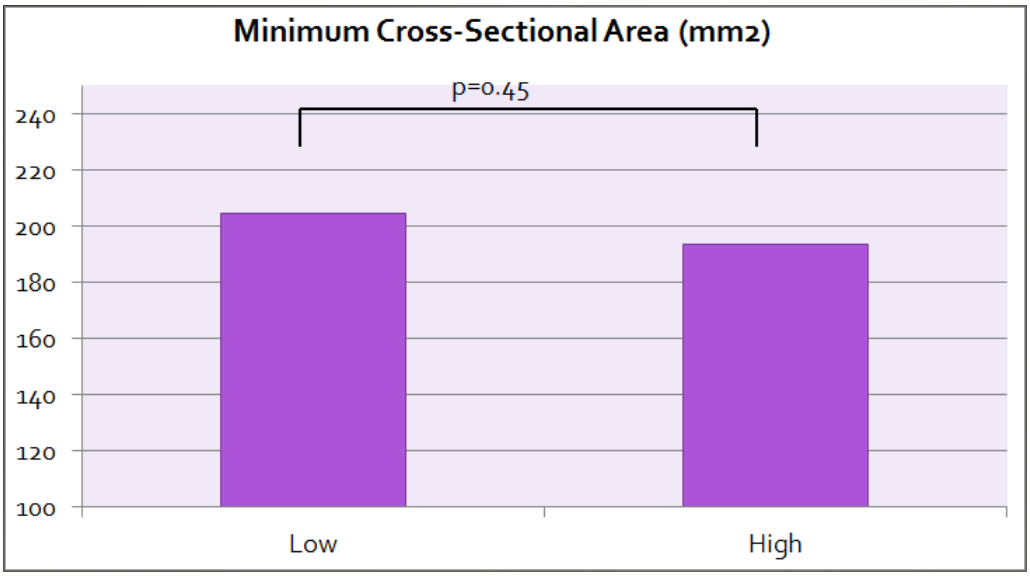

Figure 4-3. Minimum Cross-Sectional Area vs Risk for Daytime Sleepiness

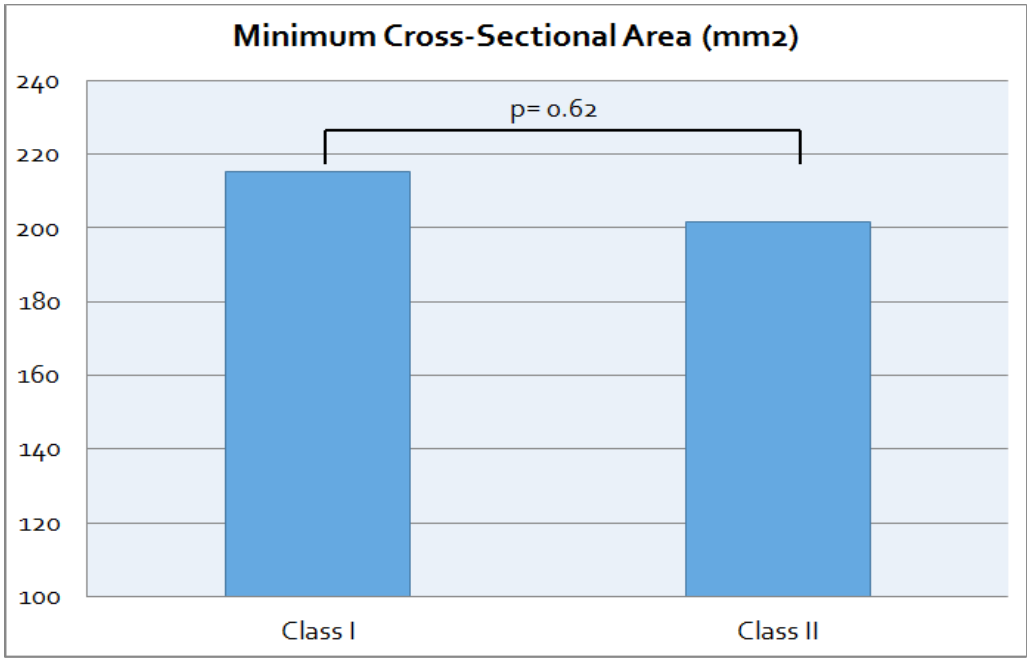

Figure 4-4. Minimum Cross-Sectional Area vs Skeletal Malocclusion

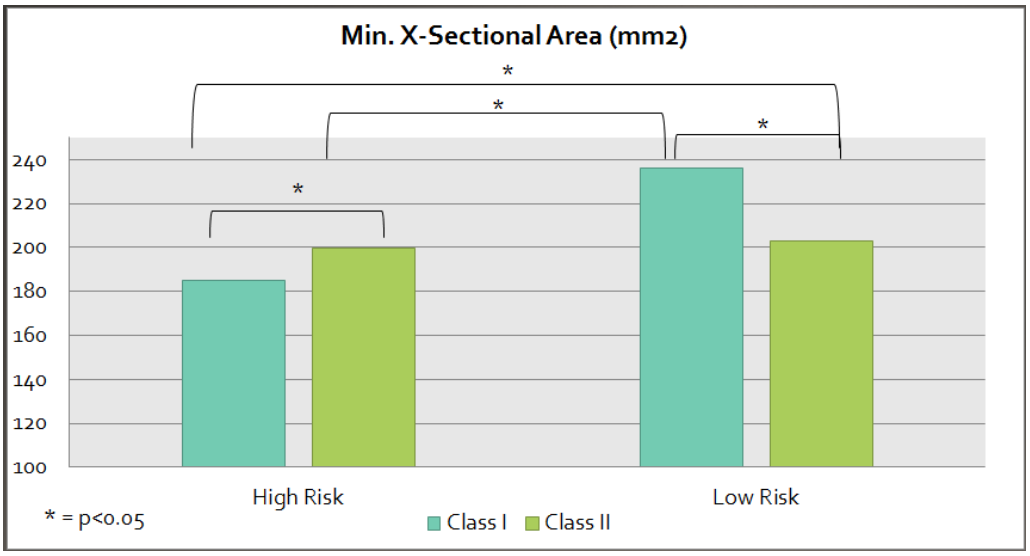

Figure 4-5. Minimum Cross-Sectional Area for Subgroups

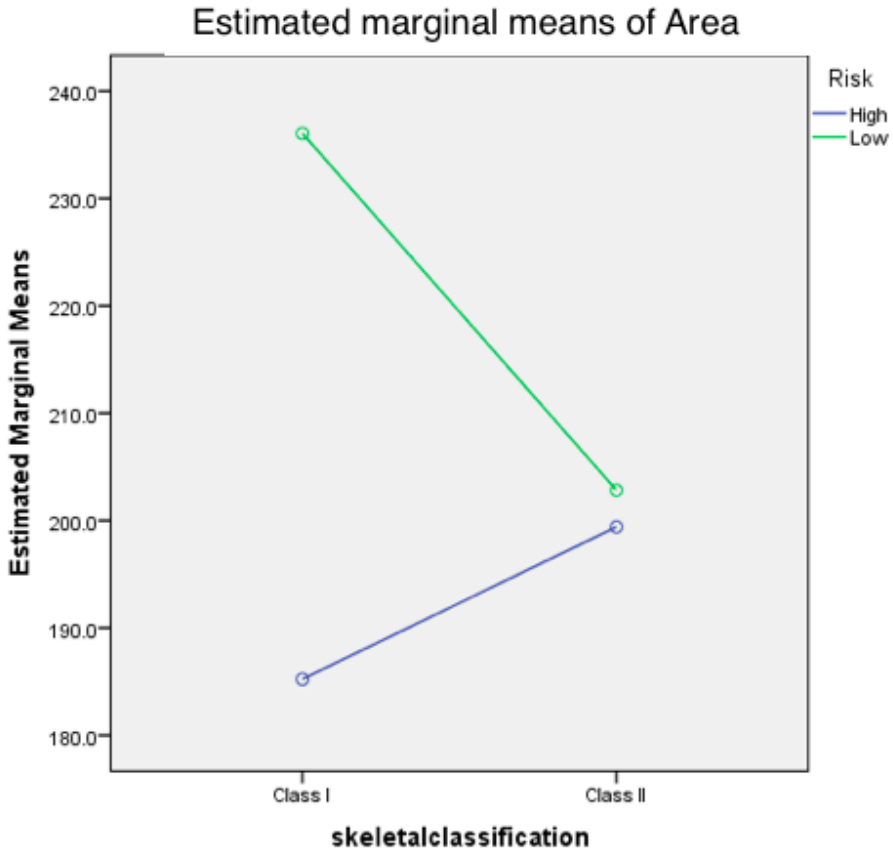

Figure 4-6. Profile plot for Airway Minimum Cross-Sectional Area

Two-tailed, Mann-Whitney U tests were performed to evaluate each airway aspect (airway volume, minimum cross sectional airway area, or airway shape at the minimum cross sectional area) in relation to malocclusion classification. Two-Tailed, Mann-Whitney U tests were also performed to evaluate each airway aspect to risk of sleep disordered breathing. Two-way Analysis of Variance (ANOVA) with pair- wise comparisons was performed to evaluate the interaction of each airway characteristic with a combination of malocclusion along with risk. A statistical significance of *P* value of <0.05 was given. See Appendix D for complete statistical analysis tables.

The data between the airway volume and minimum cross-sectional area by age were shown using scatterplots (Figure 4-1 and 4-2). There was no significant difference between the airway minimal cross-sectional area in patients classified as high risk versus patients classified as low risk (Figure 4-3; p=0.45; Mean High=193.6, Mean Low=204.3). There was no significant difference between the airway minimum cross-sectional area in patients with skeletal classification I versus patients with skeletal classification II (Figure 4-4; p=0.62; Mean Class I=215.4, Mean Class II=201.6). There was a significant interaction between the airway minimum cross-sectional area and patients with risk for excessive daytime sleepiness and skeletal malocclusion (Figure 4-5; p<0.001). The profile plot is a visual representation of the marginal means table (Figure 4-6). The factor levels of *skeletal classification* are shown along the horizontal axis. Separate lines are produced for each level of *Risk.* The difference is greater for high risk class II patients because the high risk line climbs while the line for low risk class II moves downward.

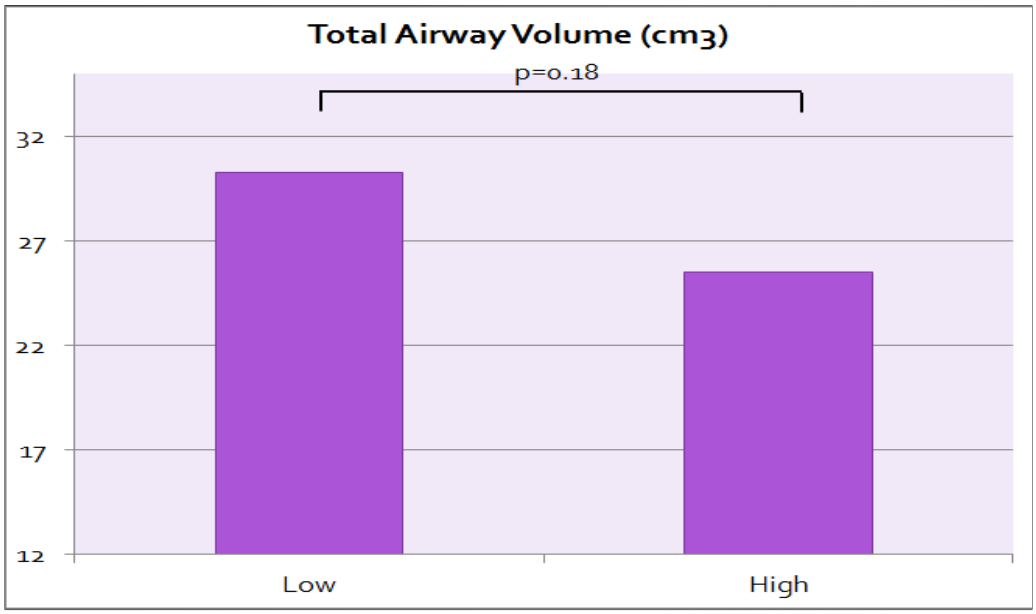

Figure 4-7. Total Airway Volume vs Risk for Daytime Sleepiness

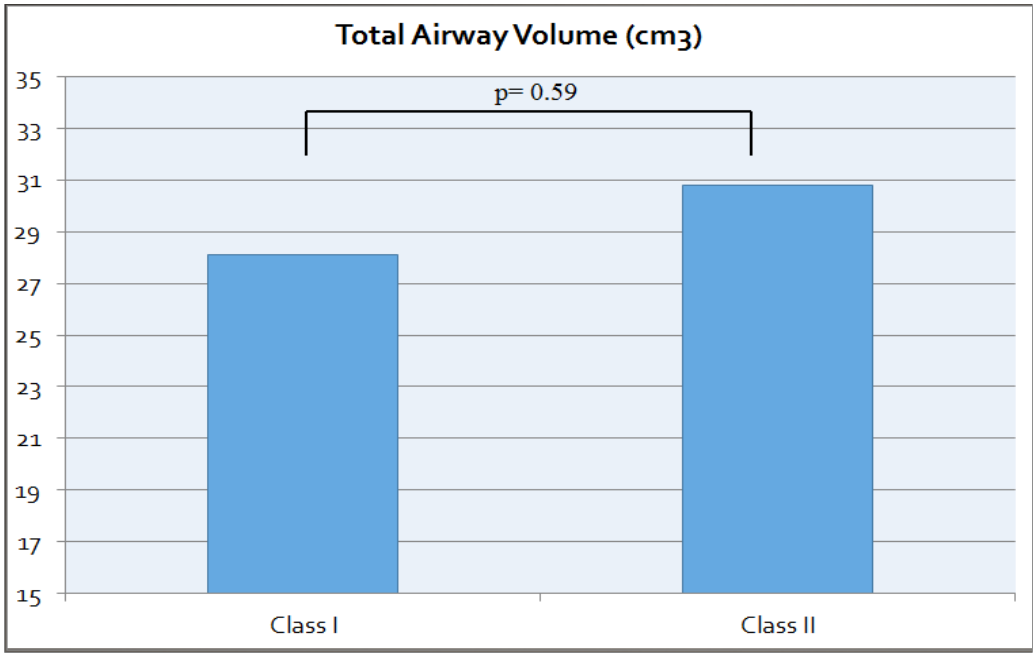

Figure 4-8. Total Airway Volume vs Skeletal Malocclusion

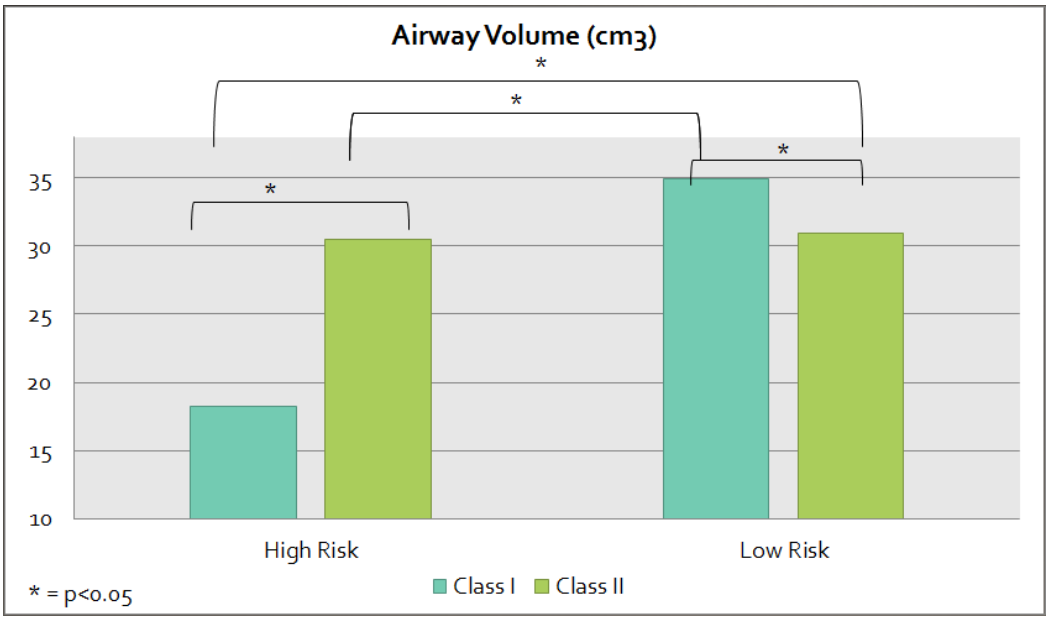

Figure 4-9. Airway Volume for Subgroups

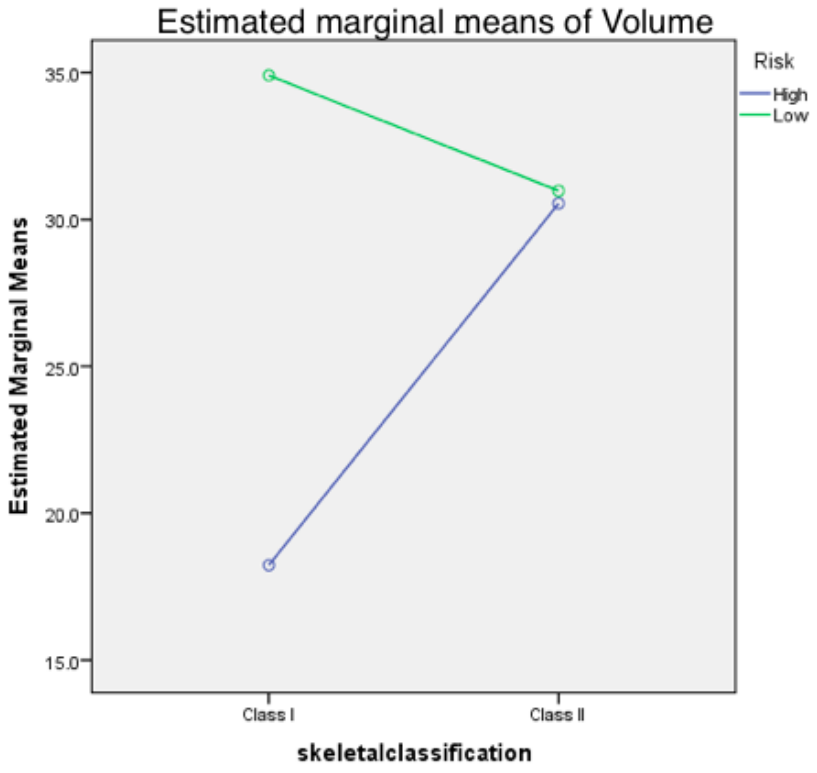

Figure 4-10. Profile plot of for Airway Volume

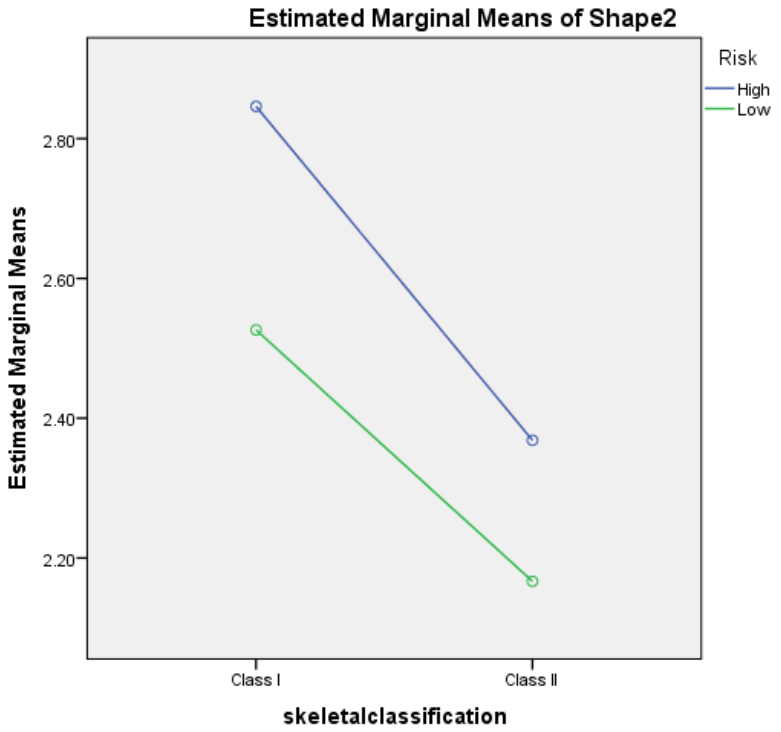

Figure 4-11. Profile plot for Airway Shape at the Minimum Cross- Sectional Area

There was no significant difference between the airway volume in patients classified as high risk vs. patients classified as low risk (Figure 4-7; p=0.18; Mean High=25.5, Mean Low=30.3). There was no significant difference between the airway volume in patients with skeletal classification I vs. patients with skeletal classification II (Figure 4-8; p=0.59; Mean Class I=28.1, Mean Class II=30.8). There was a significant interaction between the airway volume and patients with risk of excessive daytime sleepiness and skeletal classification (Figure 4-9; p<0.001). The profile plot is a visual representation of the marginal means table (Figure 4-10). The factor levels of *skeletal classification* are shown along the horizontal axis. Separate lines are produced for each level of *Risk.* The difference is greater for high risk class II patients because the high risk line climbs while the line for low risk class II moves downward.

There was no significant difference between the minimum cross-sectional area shape in patients classified as high risk versus patients classified as low risk (p=0.13). There was significant difference between the minimum cross sectional area shape in patients with skeletal classification I versus patients with skeletal classification II (p=0.02). There was no significant interaction between the minimum cross-sectional area shape and patients with risk of excessive daytime sleepiness and skeletal classification (p=0.06). The profile plot is a visual representation of the marginal means table (Figure 4-11). The factor levels of *skeletal classification* are shown along the horizontal axis. Separate lines are produced for each level of *Risk.* There was no interaction effect since the lines are more parallel to each other.

There were no significant differences in the total airway volume or minimum cross-sectional area between high risk vs. low risk patients (p=0.18, p=0.45) or between Skeletal Class I vs. Class II (p=0.59, p=0.62). There were significant interactions in the total airway volume (p<0.001) and minimum cross-sectional area (p<0.001) between skeletal classification and risk for daytime sleepiness. The mean difference in airway volume was greater between high risk and low risk in skeletal Class I (MD=17), while the mean difference in airway volume was much less apparent between high and low risk with skeletal Class II (MD=0.4). The mean difference in minimum cross-sectional area was also greater between high and low risk patients in Class I (MD=51), while the mean difference in minimum cross-sectional area was much less apparent in Class II (MD=3). There were no significant differences or interaction in cross section shape between the skeletal Class I and Class II in high risk vs. low risk patients (p=0.06). No significant difference and no significant interaction in gender among all categories (p= 0.55, p=0.

Chapter 5 : Discussion

Obstructive sleep apnea is a chronic and potentially life threatening disease that is caused by obstructions of the airway and characterized by repetitive episodes of interrupted breathing while sleeping. The periodic cessation of breathing and interrupted sleep results in excessive daytime sleepiness (Tikku et al., 2016). The Epworth Sleepiness Scale (ESS) has been shown to have a high reliability and high level of internal consistency and therefore, it is a simple and practical method for measuring daytime sleepiness in adults (Johns, 1992). The ESS has also been used to initiate treatment for OSA syndromes (Isaac, Clarke, Islam, & Samuel, 2017).

Our study used the Epworth Sleepiness Scale to evaluate high or low risk for excessive daytime sleepiness. Therefore, we considered daytime sleepiness as the determining risk factor for OSA. The results of this study showed that there was no significant difference between the airway volumes in patients classified as high risk versus patients classified as low risk for excessive daytime sleepiness. In contrast, other studies have found lower airway volume in patients with OSA. In the study by Ogawa et al (2005), it was found that patients with OSA had lower oropharyngeal airway space than patients without OSA. One reason for the possible discrepancy between the findings is there are other confounding risk factors in our data that may have affected the results. Since the data in our study lack information on BMI and ethnicity, it is possible that individuals in our low risk group had higher BMIs and/or included OSA-susceptible ethnic groups. In the study by Tikku et al. (2016), patients with OSA were evaluated against a non-OSA control group. The ESS was also used in their study as one of the determining factors for the OSA group (ESS score >10). However, their study additionally used the STOP-BANG

questionnaire as another determining factor for OSA. The STOP-BANG questionnaire accounts for other variables such as BMI, neck circumference, and high blood pressure.

Our results also showed there was no significant difference between the airway volume in patients with skeletal classification I vs. patients with skeletal classification II. This is in contrast to the findings of another study which found that the airway volume is less in skeletal Class II individuals using ANB angle (Paul, Varma, & Ajith, 2015). In that study, it was found that a strong association exists between airway and skeletal pattern with a reduced airway in Class II patient versus Class I patients. Similarly, in a study by El & Palomo (2011), it was found that the airway volumes in Class II patients were the smallest compared to other anteroposterior malocclusions. A study by Grauer et al. (2009) also found that airway volume was related to different anteroposterior jaw relationships. In his study, Class II patients have a smaller airway volume than Class I or Class III patients. One explanation for the contrast in our findings is that our studies used different landmarks and borders for airway volume determination. In some studies, the most anterior inferior point of the C2 vertebra has been used as the lower border for determining airway volume (Grauer et al., 2009). Our lower border extended to the inferior border of the hyoid bone. Therefore, this different region of evaluation could have other variables or structures that could influence the airway volume. Other confounding factors could be BMI and ethnicity.

Our study also found no significant difference between the minimum cross-sectional area in patients with skeletal classification I vs. patients with skeletal classification II. This finding is contrasted by a study by Paul et al. (2015), which concluded that airway area is significantly reduced in subjects who were skeletal Class II compared to Class I. However, the study by Paul

et al. (2015) looked at the total airway area and not just at the minimum cross section. Therefore, it is possible that Class I patients may have an overall larger total area even though their most constricted part may be similar to that of Class II. The location of the minimum cross-sectional area may also be another factor to consider. The location of the minimum cross-sectional area not only varies within the selected region of interest but may depend on the defining borders of the ROI as well. This can also be explained in part due to the variability and tortuous anatomy of the airway. This shows that it may not only be skeletal classification that affects the minimum cross-sectional area but may also be caused by other anatomic factors. This idea is supported when another coplanar aspect of airway is studied. Malocclusion has been shown to not influence pharyngeal airway widths (de Freitas et al., 2006).

There was no significant difference between the minimum cross-sectional area in patients classified as high risk vs. patients classified as low risk. This finding was supported by another study (Shigeta, Enciso, Ogawa, Shintaku, & Clark, 2008), in which the airway cross sectional area was not statistically significant different between OSA patients and control groups. However, other studies have shown that there is a smaller minimum cross-sectional area in OSA patients (Ogawa et al., 2007). Our study used the Epworth Sleepiness Scale to measure daytime sleepiness which is a risk factor for OSA. However, the ESS does not take into account other influences that may affect the responses to the questionnaire such as obesity, gender, and ethnicity (Hesselbacher, 2012). The ESS is affected by many factors and its ability to predict OSA is modest. Therefore, caution must be taken when interpreting the ESS values.

There was also no significant interaction between the shape at the minimum cross-sectional area with any category. This was due to the nature of the variability in the shapes of

airway making it difficult to create distinct categories which limited the investigation in this area. There were also no differences in gender. This is contradictory to studies that show there is male predilection in OSA (Punjabi, 2008). One possible explanation for the discrepancy is that our age group contains a range that includes post-menopausal women. The prevalence of OSA has been shown to increase in post-menopausal women (Bixler et al., 2001). Women with OSA are likely to be underdiagnosed as they may have different manifestations than men (Quintana-Gallego et al., 2004).

In our study, two significant interactions were concluded. First, there is a significant interaction between the total airway volume and skeletal classification in high risk vs. low risk patients. Second, there was a significant interaction between the minimum cross-sectional area of the airway and skeletal classification in high risk vs. low risk patients. Our findings are significant because our study comparatively investigates airway aspects in regards to malocclusions as well as consideration of indirect risk for OSA. Other studies that have studied the airway structure in regard to malocclusions only (Grauer et al., 2009; Silva et al., 2015) or OSA only (Ogawa et al., 2005; Tikku et al., 2016). Studies that investigated both malocclusion and OSA in regard to changes in upper airway structure (Lowe et al., 1996; Ono, Lowe, Ferguson, & Fleetham, 1996) have different focuses. In the study by Ono et al. (1996), they focused only class I skeletal classifications. In Lowe et al. (1996), although they studied airway structure in terms of different skeletal classification subtype with OSA, it was a cephalometric study so they were limited with the 2-dimensional image. Our study also showed that patients who are skeletal Class II have a smaller mean difference in airway volume and minimum cross-sectional area than patients who are skeletal Class I in both high risk and low risk categories.

Understanding OSA is important from a health, social, and economic standpoint. Untreated OSA can lead to a number of health problems such as high blood pressure, heart complications, diabetes, and depression. Having increased daytime sleepiness can negatively affect social functioning, work performance and ability to operate machinery and motor vehicles. The economic cost of decreased workplace performance and higher risk of automobile accidents is likely to be important (Isaac et al., 2017).

Limitations and Future Studies

The retrospective nature of this study has inherent drawbacks. The study is limited to the available information. The dental records available had a lack of reporting BMI, neck circumference, and ethnicity. The study's sample was limited to the patient pool in the dental records from UNLV School of Dental Medicine. It is not representative of the entire population at large; therefore, caution must be made in extrapolating results to the entire population. The Epworth Sleepiness Scale (which evaluate daytimes sleepiness) as a substitute for OSA screening questionnaire and/or polysomnograms (which is the standard for OSA diagnosis) is another limitation because polysomnograms provide better and more accurate diagnosis of OSA. Due to the large shape variety of the airway at the minimum cross-sectional area, it was difficult to create shape categories to evaluate relationships. CBCT imaging at UNLV School of Dental Medicine is done with the patient in an upright position and in a woken state so the sleeping (supine) position and its regulatory mechanisms are not taken into consideration. Therefore, morphometric measurements may not be an accurate representation of what actually occurs during sleep.

In this study, Class I and Class II malocclusions were investigated in addition to high and low risk for excessive daytime sleepiness with respect to various aspects of the airway. Possible future studies could include Class III malocclusions and investigating the changes of having a protruded jaw position. Additionally, this study excluded hyperdivergent skeletal growth pattern. Subsequent studies can analyze different vertical growth patterns (hypodivergent, normal, and hyperdivergent) along with risk of excessive daytime sleepiness and how those factors would affect any the changes in airway volume, cross-sectional area, and shape. Furthermore, other risk factors such as BMI and ethnicity can be included into the study in order to evaluate how other factors influence the airway. Morphologic measurements are limited and cannot account for the complex pathophysiology of OSA; therefore, future studies can also incorporate the physiologic aspect of sleep in order to gain a more comprehensive understanding of changes that occur in the airway during sleep. Additionally, a similar study to our study can be conducted to investigate the relationship of airway measurements to malocclusions and risk of OSA in children.

Conclusions

The aim of this study was to evaluate skeletal malocclusions and risk of excessive daytime sleepiness as a risk factor of OSA in relation to different aspects of the airway. Skeletal classification itself did not have a significant impact on total airway volume, airway minimum cross-sectional area, or airway shape at the minimum cross-sectional area. Similarly, risk for excessive daytime sleepiness itself did not have a significant impact on total airway volume, airway minimum cross-sectional area, or shape at the minimum cross-sectional area. However, a combination of skeletal classification and risk for daytime sleepiness did have a significant impact on airway volume and minimum cross-sectional area. Patients who are skeletal Class II

have a lesser mean difference in total airway volume and minimum cross-sectional area than patients who are skeletal Class I in high risk and low risk categories. However, we had limited BMI and ethnicity data which also hindered further investigations in some areas. Identifying risk factors and how they relate to each other can elucidate keys to preventing OSA or minimizing the negative effects of OSA. It will allow for better treatment options and to avoid treatments that could compromise the airway in those at risk. The anatomy and physiology of the airway along with the complexity of the sleep process allows for much further research into the mechanisms and confounding factors of OSA.

Appendix A: IRB Approval Form

IRBNet ID: 837924-2 USER PROFILE LOGOUT

IRBNet

Welcome to IRBNet
Tanya Al-talib

Help
My Projects
Create New Project
My Reminders (65)

Project Administration
Project Overview
Designer
Share this Project
Sign this Package
Submit this Package
Delete this Package
Send Project Mail
Reviews
Project History
Create a New Package
Messages & Alerts (10)

Other Tools
Forms and Templates

Review Details

[837924-2] 3 Dimensional airway analysis of archival dental records

UNLV Biomedical IRB, Las Vegas, NV

Submission Details

Submitted To UNLV Biomedical IRB, Las Vegas, NV
Submitted by Tanya Al-talib
Submission Date 01/27/2016
Submission Type Amendment/Modification
Local Board Reference Number

Review Details:

Agenda	Review Type	Board Action	Effective Date	Project Status	Expiration Date
06/30/2016 12:00 PM	Administrative Review	Acknowledged	01/29/2016	Research - Not HSR	

Board Documents:

There are currently no documents from UNLV Biomedical IRB.

Appendix B: Epworth Sleepiness Scale

Name: _____ Today's date: _____

Your age (Yrs): _____ Your sex (Male = M, Female = F): _____

How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired?

This refers to your usual way of life in recent times.

Even if you haven't done some of these things recently try to work out how they would have affected you.

Use the following scale to choose the **most appropriate number** for each situation:

0 = would **never** doze
1 = **slight chance** of dozing
2 = **moderate chance** of dozing
3 = **high chance** of dozing

It is important that you answer each question as best you can.

Situation	**Chance of Dozing (0-3)**
Sitting and reading	
Watching TV	
Sitting, inactive in a public place (e.g. a theatre or a meeting)	
As a passenger in a car for an hour without a break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after a lunch without alcohol	
In a car, while stopped for a few minutes in the traffic	

http://epworthsleepinessscale.com/about-the-ess/

Appendix C: UNLV Epworth Sleepiness Scale

Epworth Scale

0= Never 2= Moderate Chance
1= Slight Chance 3=Regularly

In contrast to feeling tired, are you likely to doze or fall asleep in the following situations?

- _____ Sitting & Reading?
- _____ Watching Television?
- _____ Sitting inactive in a public place (i.e. theater)?
- _____ Passenger in a car for an hour without a break?
- _____ Lying down to rest in the afternoon?
- _____ Sitting and talking to someone?
- _____ Sitting quietly after lunch without alcohol?
- _____ In a car while stopped for a few minutes in traffic?

_____ **Total Score**

Appendix D: Statistical Analysis Tables

ANALYSIS OF AIRWAY MINIMUM CROSS-SECTIONAL AREA IN HIGH VS LOW RISK PATIENTS

Mann-Whitney U Test

Group Statistics

	Risk	N	Mean	Std. Deviation	Std. Error Mean
Area	High	32	193.644	105.5231	18.6540
	Low	55	204.302	131.8617	17.7802

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Area	Equal variances assumed	.330	.567	-.756	85
	Equal variances not assumed			-.802	76.613

Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
Area	Equal variances assumed	.452	-20.6581	27.3272	-74.9919
	Equal variances not assumed	.425	-20.6581	25.7703	-71.9774

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Area	Equal variances assumed	33.6758
	Equal variances not assumed	30.6613

ANALYSIS OF AIRWAY MINIMUM CROSS-SECTIONAL AREA IN CL I VS CL II SKELETAL PATIENTS

Mann-Whitney U Test

Group Statistics

	skeletalclassification	N	Mean	Std. Deviation	Std. Error Mean
Area	Class I	32	215.406	116.2239	20.5457
	Class II	55	201.640	126.9416	17.1168

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Area	Equal variances assumed	.120	.730	.503	85
	Equal variances not assumed			.515	69.693

Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
Area	Equal variances assumed	.616	13.7663	27.3782	-40.6690
	Equal variances not assumed	.608	13.7663	26.7415	-39.5722

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Area	Equal variances assumed	68.2015
	Equal variances not assumed	67.1047

ANALYSIS OF AIRWAY MINIMUM CROSS-SECTIONAL AREA IN HIGH VS LOW RISK CL I VS CL II SKELETAL PATIENTS

Two-way Analysis of Variance

Between-Subjects Factors

		Value Label	N
skeletalclassification	1	Class I	32
	2	Class II	55
Risk	1	High	32
	2	Low	55

Descriptive Statistics

Dependent Variable: Area

skeletalclassification	Risk	Mean	Std. Deviation	N
Class I	High	185.231	85.1660	13
	Low	236.053	131.6081	19
	Total	215.406	116.2239	32
Class II	High	199.400	119.3966	19
	Low	202.822	132.3868	36
	Total	201.640	126.9416	55
Total	High	193.644	105.5231	32
	Low	214.302	131.8617	55
	Total	206.703	122.6048	87

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Area

F	df1	df2	Sig.
.156	3	83	.925

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.[a]

a. Design: Intercept + skeletalclassification + Risk + skeletalclassification * Risk

Tests of Between-Subjects Effects

Dependent Variable: Area

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	23915.872[a]	3	7971.957	.521	.669
Intercept	3229894.032	1	3229894.032	211.282	.000
skeletalclassification	1730.432	1	1730.432	.113	.737
Risk	14013.929	1	14013.929	.917	.341
skeletalclassification * Risk	10700.528	1	10700.528	.700	.405
Error	1268830.697	83	15287.117		

Total	5009936.020	87			
Corrected Total	1292746.569	86			

Tests of Between-Subjects Effects

Dependent Variable: Area

Source	Partial Eta Squared
Corrected Model	.019
Intercept	.718
skeletalclassification	.001
Risk	.011
skeletalclassification * Risk	.008
Error	
Total	
Corrected Total	

a. R Squared = .019 (Adjusted R Squared = -.017)

Estimated Marginal Means

skeletalclassification * Risk

Dependent Variable: Area

skeletalclassification	Risk	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Class I	High	185.231	34.292	117.026	253.436
	Low	236.053	28.365	179.635	292.470
Class II	High	199.400	28.365	142.983	255.817
	Low	202.822	20.607	161.836	243.808

ANALYSIS OF AIRWAY VOLUME IN HIGH VS LOW RISK PATIENTS

Mann-Whitney U Test

Group Statistics

	Risk	N	Mean	Std. Deviation	Std. Error Mean
Volume	High	32	25.544	15.4653	2.7339
	Low	55	30.335	25.5236	3.4416

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means	
	F	Sig.	t	df

Volume	Equal variances assumed	3.272	.074	-1.364	85
	Equal variances not assumed			-1.545	84.820

Independent Samples Test

		t-test for Equality of Means			
					95% Confidence Interval of the Difference
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower
Volume	Equal variances assumed	.176	-6.7908	4.9769	-16.6863
	Equal variances not assumed	.126	-6.7908	4.3953	-15.5301

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Volume	Equal variances assumed	3.1047
	Equal variances not assumed	1.9485

ANALYSIS OF AIRWAY VOLUME IN CL I VS CL II SKELETAL PATIENTS

Mann-Whitney U Test

Group Statistics

	skeletalclassification	N	Mean	Std. Deviation	Std. Error Mean
Volume	Class I	32	28.131	24.8238	4.3883
	Class II	55	30.829	21.2026	2.8590

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Volume	Equal variances assumed	.002	.966	-.537	85
	Equal variances not assumed			-.515	57.005

Independent Samples Test

		t-test for Equality of Means			
					95% Confidence Interval of the Difference
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower
Volume	Equal variances assumed	.593	-2.6978	5.0226	-12.6842
	Equal variances not assumed	.608	-2.6978	5.2374	-13.1856

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Volume	Equal variances assumed	7.2885
	Equal variances not assumed	7.7899

ANALYSIS OF AIRWAY VOLUME IN HIGH VS LOW RISK CL I VS CL II SKELETAL PATIENTS

Two-way Analysis of Variance

Between-Subjects Factors

		Value Label	N
skeletalclassification	1	Class I	32
	2	Class II	55
Risk	1	High	32
	2	Low	55

Descriptive Statistics

Dependent Variable: Volume

skeletalclassification	Risk	Mean	Std. Deviation	N
Class I	High	18.231	10.4961	13
	Low	34.905	29.4719	19
	Total	28.131	24.8238	32
Class II	High	30.547	16.5352	19
	Low	30.978	23.5141	36
	Total	30.829	21.2026	55
Total	High	25.544	15.4653	32

	Low	32.335	25.5236	55
	Total	29.837	22.4970	87

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Volume

F	df1	df2	Sig.
2.287	3	83	.085

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.[a]

a. Design: Intercept + skeletalclassification + Risk + skeletalclassification * Risk

Tests of Between-Subjects Effects

Dependent Variable: Volume

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2295.656[a]	3	765.219	1.540	.210
Intercept	62616.378	1	62616.378	126.052	.000
skeletalclassification	335.187	1	335.187	.675	.414
Risk	1393.466	1	1393.466	2.805	.098
skeletalclassification * Risk	1256.741	1	1256.741	2.530	.116
Error	41230.187	83	496.749		
Total	120976.160	87			
Corrected Total	43525.842	86			

Tests of Between-Subjects Effects

Dependent Variable: Volume

Source	Partial Eta Squared
Corrected Model	.053
Intercept	.603
skeletalclassification	.008
Risk	.033
skeletalclassification * Risk	.030
Error	

Total	
Corrected Total	

a. R Squared = .053 (Adjusted R Squared = .019)

Estimated Marginal Means

skeletalclassification * Risk

Dependent Variable: Volume

skeletalclassification	Risk	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Class I	High	18.231	6.182	5.936	30.526
	Low	34.905	5.113	24.735	45.075
Class II	High	30.547	5.113	20.377	40.717
	Low	30.978	3.715	23.589	38.366

ANALYSIS OF AIRWAY SHAPE AT MINIMUM CROSS SECTIONAL AREA IN HIGH VS LOW RISK PATIENTS

Mann-Whitney U Test

Group Statistics

	Risk	N	Mean	Std. Deviation	Std. Error Mean
Shape2	High	32	2.5625	.66901	.11827
	Low	55	2.2909	.87502	.11799

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Shape2	Equal variances assumed	3.596	.061	1.516	85
	Equal variances not assumed			1.626	78.676

Independent Samples Test

	t-test for Equality of Means

		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
Shape2	Equal variances assumed	.133	.27159	.17920	-.08471
	Equal variances not assumed	.108	.27159	.16706	-.06095

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Shape2	Equal variances assumed	.62789
	Equal variances not assumed	.60413

ANALYSIS OF AIRWAY MINIMUM CROSS SECTIONAL AREA CL I VS CL II SKELETAL PATIENTS

Mann-Whitney U Test

Group Statistics

	skeletalclassification	N	Mean	Std. Deviation	Std. Error Mean
Shape2	Class I	32	2.6563	.74528	.13175
	Class II	55	2.2364	.81567	.10999

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Shape2	Equal variances assumed	.498	.482	2.388	85
	Equal variances not assumed			2.447	69.802

Independent Samples Test

	t-test for Equality of Means

		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
Shape2	Equal variances assumed	.019	.41989	.17580	.07034
	Equal variances not assumed	.017	.41989	.17162	.07758

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Shape2	Equal variances assumed	.76943
	Equal variances not assumed	.76219

ANALYSIS OF AIRWAY SHAPE AT MINIMUM CROSS SECTIONAL AREA IN HIGH VS LOW RISK CL I VS CL II SKELETAL PATIENTS

Two-way Analysis of Variance

Between-Subjects Factors

		Value Label	N
Risk	1	High	32
	2	Low	55
skeletalclassification	1	Class I	32
	2	Class II	55

Descriptive Statistics

Dependent Variable: Shape2

Risk	skeletalclassification	Mean	Std. Deviation	N
High	Class I	2.8462	.68874	13
	Class II	2.3684	.59726	19
	Total	2.5625	.66901	32
Low	Class I	2.5263	.77233	19
	Class II	2.1667	.91026	36
	Total	2.2909	.87502	55

Total	Class I	2.6563	.74528	32
	Class II	2.2364	.81567	55
	Total	2.3908	.81206	87

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Shape2

F	df1	df2	Sig.
1.793	3	83	.155

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.[a]
a. Design: Intercept + Risk + skeletalclassification + Risk * skeletalclassification

Tests of Between-Subjects Effects

Dependent Variable: Shape2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.862[a]	3	1.621	2.595	.058
Intercept	467.507	1	467.507	748.369	.000
Risk	1.296	1	1.296	2.074	.154
skeletalclassification	3.340	1	3.340	5.346	.023
Risk * skeletalclassification	.066	1	.066	.106	.745
Error	51.850	83	.625		
Total	554.000	87			
Corrected Total	56.713	86			

Tests of Between-Subjects Effects

Dependent Variable: Shape2

Source	Partial Eta Squared
Corrected Model	.086
Intercept	.900
Risk	.024
skeletalclassification	.061
Risk * skeletalclassification	.001
Error	

Total	
Corrected Total	

a. R Squared = .086 (Adjusted R Squared = .053)

ANALYSIS OF GENDER

Independent Samples Test

		Levene's Test for Equality of Variances	t-test for Equality of Means						
								95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Risk	Equal variances assumed	1.483	.226	-.600	96	.550	-.060	.099	-.257	.137
	Equal variances not assumed			-.603	89.937	.548	-.060	.099	-.256	.137
Class	Equal variances assumed	1.169	.282	.534	96	.595	.054	.100	-.146	.253
	Equal variances not assumed			.536	89.539	.593	.054	.100	-.145	.252

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