Université de Montréal

Sleep-disordered breathing in the child and adolescent orthodontic patient

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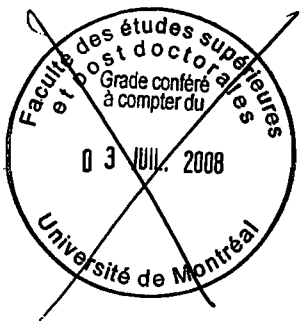

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Ce mémoire intitulé :

Sleep-disordered breathing in the child and adolescent orthodontic patient

présenté par :

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RÉSUMÉ

Introduction : Les troubles respiratoires du sommeil représentent un continuum de symptômes allant du ronflement primaire jusqu'à l'apnée obstructive du sommeil (AOS). Ces troubles ont des effets significatifs sur la santé globale des enfants, ainsi que sur leur comportement et sur leur performance scolaire. Bien que plus souvent associées avec une hypertrophie adénoïdienne et amygdalienne, des malformations craniofaciales contribuent autant au désordre. *Objectif :* L'objectif de cette étude transversale est double: 1. de déterminer la prévalence des troubles respiratoires du sommeil chez une population orthodontique et d'évaluer les facteurs morphologiques qui leurs sont associés, et 2. de déterminer les relations statistiques entre les caractéristiques du patient impliquées dans les dimensions réduites des voies aériennes supérieures et les symptômes d'AOS. *Matériels et méthodes :* 604 sujets âgés de 7 à 17 ans se présentant pour une évaluation orthodontique à une clinique universitaire. Les parents ont complété un questionnaire de santé et de sommeil sur leur enfant avant l'évaluation à la clinique d'orthodontie. *Résultats :* La prévalence des facteurs morphologiques, l'état de santé et les symptômes d'AOS pédiatriques signalés reflètent ceux trouvés dans la population pédiatrique en général. Des relations significatives ont été démontrées entre les facteurs morphologiques et les symptômes d'AOS. Le tableau clinique de ces caractéristiques a été celui d'un patient avec le syndrome *long-face* : dolichofacial, plan mandibulaire ouvert, palais étroit, chevauchements sévères au maxillaire et à la mandibule, allergies, rhumes fréquents et respiration buccale. Les facteurs associés à une déficience mandibulaire ont démontré un manque de relations positives. *Conclusion :* En tant que spécialiste de la santé examinant les caractéristiques morphologiques des jeunes patients en croissance, un orthodontiste devrait toujours évaluer la possibilité de troubles respiratoires du sommeil.

Mots clés : Apnée du sommeil, malocclusion, obstruction, prévalence, respiration buccale, ronflement, voies aériennes

ABSTRACT

Introduction: Childhood sleep-disordered breathing (SDB) represents a continuum of disorders ranging from primary snoring to obstructive sleep apnea (OSA). SDB has significant effects on a child's health, behaviour, and performance. Though most frequently associated with adenotonsillar hypertrophy, craniofacial malformations also contribute to the disorder. *Objective:* The aim of this cross-sectional study is twofold: 1. to determine the prevalence of sleep disordered breathing and associated morphological and health-related factors in an orthodontic population, and 2. to determine statistical relationships between patient characteristics implicated in reduced upper airway dimensions and OSA symptoms reported from a pediatric sleep questionnaire. *Materials and Methods:* Subjects were 604 patients aged 7 to 17 years presenting for orthodontic screening in a university clinic. The parents completed a health and sleep behaviour questionnaire prior to the child being evaluated in the orthodontic clinic. *Results:* The prevalence of morphological factors, reported health-features, and reported pediatric OSA symptoms mirrored those found in the general pediatric population. Positive relationships were found between morphological factors and pediatric OSA symptoms. The clinical picture of those characteristics found to be statistically significant was that of a long-face syndrome patient: dolichofacial, high mandibular plane angle (MPA), narrow palate, severe crowding of the maxilla and mandible, allergies, frequent colds, and habitual mouth breathing. Factors associated with reduced antero-posterior dimensions were not related with SDB. *Conclusion:* As a health specialist who examines the morphological characteristics of patients, an orthodontist should always be screening for possible SDB in growing patients.

Key words: Malocclusion, mouth breathing, obstruction, prevalence, sleep apnea, snoring, upper airway

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LIST OF ABBREVIATIONS

%	Percent
ADHD	Attention-Deficit/Hyperactivity Disorder
AI	Apnea Index
AHI	Apnea-Hypopnea Index
ANOVA	Analysis of Variance
BMI	Body Mass Index
CI	Confidence Interval
CNS	Central Nervous System
CPAP	Continuous Positive Airway Pressure
EEG	Electroencephalogram
h	Hour(s)
kg	Kilogram(s)
LAUP	Laser-Assisted Uvuloplasty
m	Meter(s)
min	Minute(s)
mm	Millimeter(s)
MMA	Maxillomandibular Advancement
MPA	Mandibular Plane Angle
NHANES III	National Health and Nutrition Estimates Survey III
OB	Overbite
OJ	Overjet
OSA	Obstructive Sleep Apnea
OR	Odds Ratio
PSG	Polysomnography
RDI	Respiratory Disturbance Index
REM	Rapid Eye Movement
RPE	Rapid Palatal Expansion

RVTR	Radiofrequency Volumetric Tissue Reduction
SD	Standard Deviation
SDB	Sleep-Disordered Breathing
TMD	Temporomandibular Disorder
UARS	Upper Airway Resistance Syndrome
UPPP	Uvulo-Palatopharyngoplasty

To Elaine and David, the best teachers I could ever have.

For Amy, with love.

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INTRODUCTION

1. INTRODUCTION

Sleep-disordered breathing (SDB) encompasses a spectrum of disorders. These range from a partial obstruction of the upper airway, producing primary snoring, increasing in upper airway resistance to complete obstruction, which results in obstructive sleep apnea (OSA). SDB is characterized by recurring episodes of partial or complete obstruction of the upper airway during sleep, often in association with loud snoring. The upper airway obstruction is often associated with arousals, sleep fragmentation, non-restorative sleep, intermittent hypoxemia and hypercapnia, and nocturnal hypertension (American Thoracic Society 1996). Even simple chronic snoring is considered abnormal in a pediatric population (O'Brien 2004).

The pharynx is a single conduit which must be compliant for food propulsion and vocalization, and also be firm enough for air flow. The basis of the obstruction in OSA is a decrease in nasopharyngeal and oropharyngeal dimensions.

Obstructive sleep apnea (OSA) is a multifactorial disease. It is related to upper airway skeletal deformities, soft tissue anatomy changes, the size of lymphoid structures, height, increased weight, age, and medical conditions (Nixon 2005).

Difficulties with sleep onset occur in about 11% of children (Paavonen 2000). Primary snoring is thought to occur in 3.2% to 12.1% of the pediatric population, and OSA has been estimated to affect 0.7% to 10.3% of children (Gislason 1995, Ali 1993, Redline 1999). Adenotonsillar hypertrophy has long been identified as the primary cause of reduced airway dimensions in children. However, the obesity epidemic in the industrialized world may now be adding to the problem.

Sleep apnea has major health and social consequences. Growth may be inhibited due to OSA. Severe cardiovascular complications may result from both OSA and childhood

obesity. Learning and behaviour problems in children, such as attention-deficit hyperactivity disorder (ADHD), have shown a three-fold increase in children with SDB (American Academy of Pediatrics 2002).

Despite their impact on public health, craniofacial and orthodontic anomalies related to OSA are often ignored. Some of the abnormalities associated with OSA are related to maxillo-mandibular development. A rarely investigated, complex interaction exists between facial growth and nasal breathing (Guilleminault 2001). Pediatricians and orthodontists should therefore consider orthodontic problems as part of a growing child's overall health (Guilleminault 2005).

In an attempt to prevent the consequences of OSA, young patients with SDB should be carefully examined to rule out physical abnormalities. Clinical examination of the upper airway anatomy may identify anatomical risk factors predisposing a patient to the development of abnormal breathing during sleep. Though airway obstruction is aggravated by muscle tone changes during sleep, underlying anatomical factors, such as adenotonsillar hypertrophy, obesity, and craniofacial abnormalities predispose a patient to OSA (Primhak 2005).

Pediatric sleep questionnaires are designed to obtain maximal information from parents and children about his/her sleep behaviour. However, clinical history alone is not sufficiently reliable to distinguish OSA from primary snoring (Carroll 1995). Therefore a complete sleep evaluation is required for the final diagnosis of OSA. Though overnight polysomnography (PSG) may be the gold standard diagnostic sleep study for OSA, it is both expensive and of limited accessibility. A detailed questionnaire is extremely useful for screening prior to the diagnostic polysomnographic examination.

It is important that children and adolescents with OSA be identified and treated as early as possible, not only for their respiratory problems, but also for their dentofacial development. This requires an integrated diagnosis and management of pediatric sleep apnea. The orthodontist is well positioned in this respect as a majority of patients

presenting for orthodontic evaluations are growing children and adolescents. Many of the craniofacial structures evaluated by an orthodontist in the planning of orthodontic treatment may be related to upper airway obstruction. Other symptoms may be elucidated from medical and sleep questionnaires. The orthodontist should identify patients at-risk and refer them to sleep specialists for further study and diagnostic confirmation. Integrated within the treatment team, the orthodontist may also participate in the evaluation of the patient's growth post-adenotonsillectomy, assist in the treatment of mild to moderate OSA cases with anterior mandibular repositioning devices or palatal expansion, or prepare the pre-surgical orthodontic treatment of severe cases.

The purpose of this pilot study is to assess a child and adolescent population which presents for evaluation at a university orthodontic clinic. This epidemiological study will identify the prevalence of different skeletal and dental aspects of malocclusion and SDB/OSA parameters in this orthodontic population. It will also attempt to demonstrate statistically significant correlations between clinical signs of malocclusion and reported symptoms of SDB. It is hypothesized that deficiencies in maxillo-mandibular transverse and antero-posterior dimensions, as well as increased vertical facial height will be related to reported symptoms of SDB. However, the most important objective of this study is to increase awareness of the importance of evaluating all orthodontic patients for sleep and breathing problems in order to prevent serious long-term health and quality of life consequences.

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 Sleep-Disordered Breathing

Sleep is a delicate balance among three behavioural states: wakefulness, non-rapid eye movement sleep, and rapid eye movement (REM) sleep. The balance that exists among these states can be easily disrupted by medications, physiological and psychological factors, as well as environmental causes (Waite 1998).

At the onset of sleep, there is an increase in upper airway resistance due to a reduction in pharyngeal muscle activity (Worsnop 2000). A slight decrease in tidal volume also occurs. An increased breathing frequency normally compensates for these decreases, keeping the minute ventilation normal. Increased upper airway resistance due to physical obstructions may lead to a collapse of the upper airway. Apneic events occur in these circumstances (Guilleminault 2005).

A wide range of dyssomnias exist. Sleep disorders range from insomnia and primary snoring to OSA and narcolepsy (Waite 1998). SDB is described as a continuum of severity from primary snoring to OSA.

Primary snoring prevalence among children and adolescents has been reported to be between 3.2% and 12.1% (Ersu 2004, Gislason 1995, Ali 1993). Snoring sounds are produced by vibrations of the pharyngeal tissues due to air turbulence during inspiration. Reduced airway dimensions are associated with snoring. The prevalence of snoring increases with age, reaching between 40% and 50% of the general population above the age of 65 (Lavigne 1999). Snoring is an important indicator of apnea. Chronic snoring, though common in adulthood, should be considered abnormal in a pediatric population (O'Brien 2004).

Upper airway resistance syndrome (UARS) is a disease that presents in slim people complaining of excessive snoring and daytime fatigue, but without apnea, hypopnea, or oxygen desaturation. Sleep fragmentation and REM-sleep depravation may be related to this syndrome (Waite 1998).

Sleep apnea can be classified as obstructive, central, or mixed (Lavigne 1999). Central sleep apnea is a neurological condition resulting from a depression of the motor respiratory system. Mixed sleep apnea is a combination of obstructive and central apneas.

2.1.1 Obstructive Sleep Apnea

The American Thoracic Society (1996) defines OSA as "a disorder of breathing during sleep characterized by prolonged partial upper airway obstruction and/or intermittent complete obstruction (obstructive apnea) that disrupts normal ventilation during sleep and normal sleep patterns." Repeated episodes of partial or complete upper airway obstruction during sleep characterize OSA. This is usually accompanied by a reduction in oxygen saturation. Partial (hypopnea) or complete (apnea) obstruction results in brief awakenings from sleep, or transitions to lighter stages of sleep. Sleep fragmentation and unrefreshing sleep thus ensue.

The estimated prevalence in the general adult population is 2% to 4%, mostly affecting overweight, middle-aged males (Young 1993). Post-menopausal women are also affected. A large number of anatomic and physiological factors render OSA a complex multifactorial condition.

2.2 Pediatric Obstructive Sleep Apnea

Sleep apnea in children has a different etiology, clinical presentation and treatment. Upper airway obstruction in children is more likely to involve a reduction in airflow (hypopnea) than a complete obstruction (apnea) (Nixon 2005). Though pediatric populations experience sleep apnea, no large population based studies have evaluated pediatric OSA prevalence (Guilleminault 2005). Studies of pediatric OSA with limited sample sizes have estimated its prevalence to be between 0.7% and 10.3% (Gislason 1995, Ali 1993, Redline 1999). OSA has become recognized as one of the most common respiratory disorders of childhood, with similar rates for girls and boys (Redline 1999).

2.2.1 Diagnosis

Child and adolescent sleep-disordered breathing is often first suspected based on parental concerns. A thorough interview about sleep behaviour and SDB-associated factors should be undertaken using questionnaires. Though clinical history-taking and questioning have demonstrated low sensitivity and specificity regarding the diagnosis of SDB, it remains the primary screening tool leading to further assessment by overnight polysomnography (PSG) (American Academy of Pediatrics 2002).

Systematic parental questioning regarding their child's symptoms is essential for a child suspected of SDB. Questionnaires can give an initial indication of the problem. A variety of pediatric questionnaires exist for signs and symptoms, and quality of life implications of OSA (Chervin 2000, de Serres 2000, Owens 2000, Brouillette 1984). It is essential to evaluate a patient's medical history including: reports of snoring, daytime sleepiness, unrefreshing sleep, morning headaches, choking during sleep, memory impairments, depressive reactions, enuresis, and behavioural problems.

Much can be learned from a clinical examination. Abnormal narrowing of the nose, nasopharynx, oropharynx, or hypopharynx may lead to abnormal air flow during sleep and to clinical symptoms of SDB (Guilleminault 2005).

The gold standard diagnostic tool is the overnight sleep study. Various sleep parameters are measured by PSG and it distinguishes between the various forms of SDB to confirm the presence or absence of OSA.

2.3 Diagnostic Tools for SDB

The diagnostic tools used to evaluate pediatric patients for SDB include questionnaires, a clinical exam, diagnostic imaging, and final confirmation with the overnight PSG laboratory exam.

2.3.1 Sleep Questionnaires

Many questionnaires exist for the assessment of OSA. Standardization and validation of these questionnaires has helped in the screening of SDB. Questionnaires such as the Berlin Questionnaire, the Pittsburgh Sleep Quality Index, the Epworth Sleepiness Scale, and the Sleep Apnoea Quality of Life Index are all validated screening instruments used for adults (Netzer 1999, Buysse 1989, Chervin 1997, Lacasse 2002). In children, the Pediatric Sleep Questionnaire and the Children's Sleep Habits Questionnaire are two instruments which have recently gained in popularity (Chervin 2000, Owens 2000).

Other questionnaires have also been developed using common signs and symptoms of SDB in order to attempt to identify OSA in children. Pediatric sleep questionnaires have been available for nearly 25 years (Brouillette 1984). The difficulty of low sensitivity and specificity relating to OSA diagnosis comes from the difficulty of differentiating primary snoring from OSA (American Academy of Pediatrics 2002, Carroll 1995).

Parental reporting of sleep behaviour may be another confounding factor in reporting SDB. Some studies have demonstrated good correlation, while others question whether a parent who sleeps in another room can accurately report the sleep behaviour of a child (Lumeng 2008, Chervin 2007, Johnson 2006). One study by Chervin *et al.* (2000) has demonstrated high sensitivity and specificity between pediatric OSA-related questions and diagnosis on polysomnography.

Questionnaires are important to aid in the detection of possible SDB. However, diagnosis of OSA through clinical history and physical examination has been shown to correlate poorly with polysomnographic confirmation of the diagnosis in children. (Brietzke 2004, American Academy of Pediatrics 2002, Carroll 1995) Sleep questionnaires have difficulty in differentiating between the different severities of SDB. Given the expense and limited availability of overnight PSG, questionnaires and a clinical exam remain the most important diagnostic tools for SDB.

2.3.2 Clinical Evaluation

Since OSA may be due to upper airway obstruction, a pediatric exam as well as a thorough upper airway evaluation is required. Abnormal anatomy and/or poor pharyngeal muscle tone may result in inadequate airway patency. A multitude of clinical features are related to OSA. Risk factors for SDB are found in Table I.

Table I. Factors Implicated in Sleep-Disordered Breathing in Children and Adolescents

Craniofacial morphology

Soft Tissue

- Adenotonsillar hypertrophy
- Narrowed pharyngeal dimensions
- Nasal obstruction
- Elongated soft palate
- Macroglossia

Skeletal

- Narrow palate
- Posterior crossbite
- Long face (Adenoid facies)
- Severe dental crowding
- Mandibular retrognathism
- Severe overjet
- Inferiorly placed hyoid bone
- Maxillary hypoplasia

Other

- Muscular hypotonia
- Mouth breathing
- Asthma
- Allergies
- Allergic rhinitis
- Obesity
- Hypertension
- Congestive heart failure
- CNS depressant medications
- Alcohol
- Smoking
- Developmental delay
- Short stature
- Craniofacial syndromes

(Halbower 2006, Guilleminault 2005, Primhak 2005, Crabtree 2004, Goldstein 2004, Shin 2003, Schechter 2002, Chervin 2000, Cistulli 1996)

2.3.3 Radiological Imaging

Three dimensional imaging using magnetic resonance or computed tomography gives precise information about the soft and hard tissue anatomical structures. Imaging studies have also shown that anatomical obstruction in OSA patients occurs primarily in retropalatal and retroglossal areas (Schwab 2001).

Lateral cephalometric radiographs assess the skeletal and dental maxillary and mandibular relationships. Soft tissue relationships of the palate, tonsils and adenoids and the posterior pharynx can also be assessed. Decreased airway dimensions due to soft tissue and skeletal causes have been demonstrated by cephalometry (Lowe 1997). Cephalometric evaluation may aid in the screening of the posterior airway and in the longitudinal evaluation of treatment, but has the disadvantage of being a static two-dimensional image (Pracharktam 1996). It is, however, a useful tool in planning orthognathic surgery.

2.3.4 Polysomnography

An accurate diagnosis of respiratory pauses during nighttime sleep is based on a comprehensive monitoring of various sleep parameters. Polysomnography (PSG) recordings during sleep are the gold standard used to confirm the presence of SDB. Various physiological parameters of sleep are measured in an overnight sleep study. Monitoring of sleep/wake states through electroencephalography (EEG), electro-oculography, electrocardiography, electromyography of the chin and leg, body position, and appropriate monitoring of breathing must be included in the overnight study. Other monitoring may include nasal cannula-pressure transducer, oral thermistor, chest and abdominal belts, a neck microphone, pulse oximetry, and videotaping (Guilleminault 2005).

Recordings may be made in a sleep laboratory or in an ambulant setting. The home setting has been shown to be more acceptable to younger patients and their parents. It helps to maintain an environment that does not disrupt the child's normal sleep pattern (Nixon 2005). However, if performed in a home setting, the validity of these results is still uncertain when compared to the gold standard of overnight laboratory PSG (American Academy of Pediatrics 2002). If performed in a sleep laboratory, a parent should stay with the child throughout the night.

Diagnostic criteria for pediatric PSG differ from adult norms. Consensus on these criteria has been difficult to achieve (Sheldon 2001). Recent guidelines from the American Academy of Pediatrics (2002) and the American Thoracic Society (1996) have clarified the thresholds used for pediatric OSA. Apnea is considered as an absence of airflow at the nose and mouth lasting longer than 2 respiratory efforts. If, according to the apnea index (AI), more than 1 apneic event occurs per hour of sleep, pediatric OSA is confirmed. Hypopnea is a reduction in airflow of at least 50% in nasal flow amplitude longer than 2 breaths and may be associated with an arterial oxygen desaturation and an EEG arousal. If the apnea-hypopnea index (AHI) records at least 5 events per hour, OSA is also confirmed. The respiratory disturbance index (RDI) allows for the inclusion of other abnormal breathing events such as snoring and a corresponding EEG arousal to be included. A cut-off of at least 5 events per hour is also used to demonstrate pathological sleep breathing (Guilleminault 2005).

Following the complete medical exam and PSG testing, the diagnosis of OSA should be made by a sleep medicine or respiratory disorder specialist.

2.4 Factors Associated with SDB

Pediatric OSA has been recognized as a multifactorial disease. There is no pathognomonic sign or symptom that is clinically predictive of OSA, rendering a clinical diagnosis difficult.

2.4.1 Symptoms of SDB

Sleep-disordered breathing in children has been associated with a wide variety of clinical findings. Patients often report excessive daytime fatigue, morning headaches, insomnia, loud and abnormal snoring, restless sleep, impaired intellectual function,

mood disturbance, aggressive behaviour, and hyperactivity (Mitchell 2006). Symptoms of SDB can be divided into nighttime and daytime observations. (See Table II)

Table II. Symptoms of Sleep-Disordered Breathing in Children and Adolescents

Nighttime	Daytime

• Chronic, heavy snoring
• Difficulty breathing during sleep
• Witnessed breathing pauses during sleep
• Mouth breathing
• Restless sleep
• Periodic limb movement
• Delayed onset of sleep
• Insomnia
• Frequent awakenings
• Nocturnal migraine
• Abnormal sleeping positions
• Drooling
• Sleep talking
• Sleepwalking
• Sleep terror
• Nocturnal sweating
• Enuresis
• Difficulty waking up in the morning
• Confused arousal
	• Morning tension-type headache
	• Mouth breathing
	• Excessive morning thirst
	• Excessive fatigue and sleepiness
	• Abnormal shyness, withdrawn and depressive presentation
	• Behavioural problems
	  • Pattern of attention-deficit/ hyperactivity disorder (ADHD)
	  • Aggressiveness
	  • Irritability
	• Poor concentration
	• Learning difficulties
	• Memory impairment
	• Poor academic performance

(Beebe 2006, Halbower 2006, Guilleminault 2005, Primhak 2005, Crabtree 2004, Goldstein 2004, Shin 2003, Chervin 2002, Cistulli 1996)

2.4.2 Medications

Medications affecting dopamine, acetylcholine, serotonin, and other neurotransmitter levels in the central nervous system (CNS) also induce alterations in sleep (Pagel 2001). Central nervous system depressant medications, sedative-hypnotic drugs, antidepressants, alcohol, and smoking may also adversely affect the patient's sleep. Though uncommon in younger children, these substances may be used by older adolescents.

Alerting or psychostimulant medications such as methylphenidate (Ritalin) used in the treatment of ADHD are increasing in prevalence in the pediatric population. These medications may also adversely affect sleep quality and quantity (Sangal 2006).

2.4.3 Learning and Behaviour Problems

Childhood is a period of rapid neurological development. Sleep disruption throughout this period may lead to significant neurocognitive deficits (Kennedy 2004). Learning performance, attention and daytime behavioural problems have been demonstrated in children where SDB is present (Goldstein 2000, Gozal 1998). Hyperactivity and behaviour problems have long been described by parents of children with OSA (Ali 1993). Memory, learning and problem solving are also reduced in children with SDB (Owens 2000). Cognitive deficits and the possibility of permanent neuronal injury as sequelae to OSA have also been demonstrated (Halbower 2006).

An association exists between the presence of SDB and learning and behavioural problems; however a link between the severity of the OSA and the severity of neurocognitive scores has not been shown (Mitchell 2007, Beebe 2006, Friedman 2003).

2.4.4 Allergies and Asthma

Nasal obstruction due to allergic and infectious enlargement of tonsils and adenoids reduces the upper airway lumen and increases the symptoms of SDB. Increased nasal resistance due to occlusion inevitably leads to mouth breathing (Salem 2004). Allergic edematous conditions such as rhinitis and rhinosinusitis should be evaluated. Nasal occlusion has been related to an increase in OSA symptoms in children and adolescents. Patients that present with increased habitual snoring have an increased risk for pediatric OSA (McColley 1997, Millman 1996).

2.4.5 Medical Disorders and Syndromes

High risk groups for OSA are those children with hypothyroidism and premature birth. Syndromes with severe craniofacial malformations which result in a narrowing of the naso-pharyngeal airway are also associated with OSA (Sheldon 2001). Syndromes with severe mandibular deficiencies, such as Pierre-Robin sequence, Treacher-Collins syndrome, or those with hypoplasia of the maxilla such as Apert's and Crouzon's demonstrate SDB (Primhak 2005).

The following syndromes, which demonstrate pharyngeal muscle hypotonia, are strongly associated with OSA: Duchenne muscular dystrophy, Down syndrome, Prader-Willi syndrome, Marfan's syndrome, achondroplasia, mucopolysaccharoidosis, spina bifida, and cerebral palsy (Primhak 2005, Nixon 2005, de Miguel-Díez 2003, Cistulli 1996). Though OSA may predominate, central and mixed apneas may also occur in children with neurological abnormalities (Sheldon 2001).

2.4.6 Obesity

Over the past 25 years, the prevalence of childhood obesity has more than doubled (Whitlock 2005). A recent study of Canadian schoolchildren and adolescents has shown that approximately 26% of boys and 17% of girls are either overweight or obese (Boyce 2008). The same study found a rise in obesity from 4% to 6% between 2002 and 2006. Being overweight in childhood is associated with an increased risk for early bone maturation, type 2 diabetes mellitus, glucose intolerance, hyperlipidemia, hypertension, and other cardiovascular diseases (Dietz 1998). Significant short-term consequences are psychosocial in origin. Decreased self-esteem, quality of life and social marginalization are common (Strauss 2003). Being overweight and obese in childhood and adolescence tends to carry on into adulthood.

With the increasing prevalence of obesity, a greater percentage of the pediatric population is at-risk for OSA (Redline 1999). The deposition of adipose tissue in the upper airway may play an important role in the development of pediatric OSA (Yu 2003). SDB has been shown to be common in populations of overweight children (Verhulst 2007). However, though obesity is often related to OSA, it is not an essential factor as thin people may also have OSA.

The body mass index (BMI) is a screening tool which is used to calculate healthy weights related to the height and sex of an individual. BMI has been shown to correlate with direct measures of body fat in children and adolescents (Mei 2002). Elevated childhood BMI also predicts future adiposity, as well as future morbidity and premature mortality (Must 1999). In growing children and adolescent patients, BMI is age-specific and sex-specific in order to compensate for differences in body fat at different ages and between the sexes. This differs significantly from adult BMI which does not take age or sex into account (Kuczmarski 2000).

BMI-for-age curves have been developed by the Centers for Disease Control in the United States to evaluate the size and growth of children (Figures 1 and 2) (Kuczmarski

2000). Using percentiles, four categories have been delineated to classify children according to their weight status (Table III).

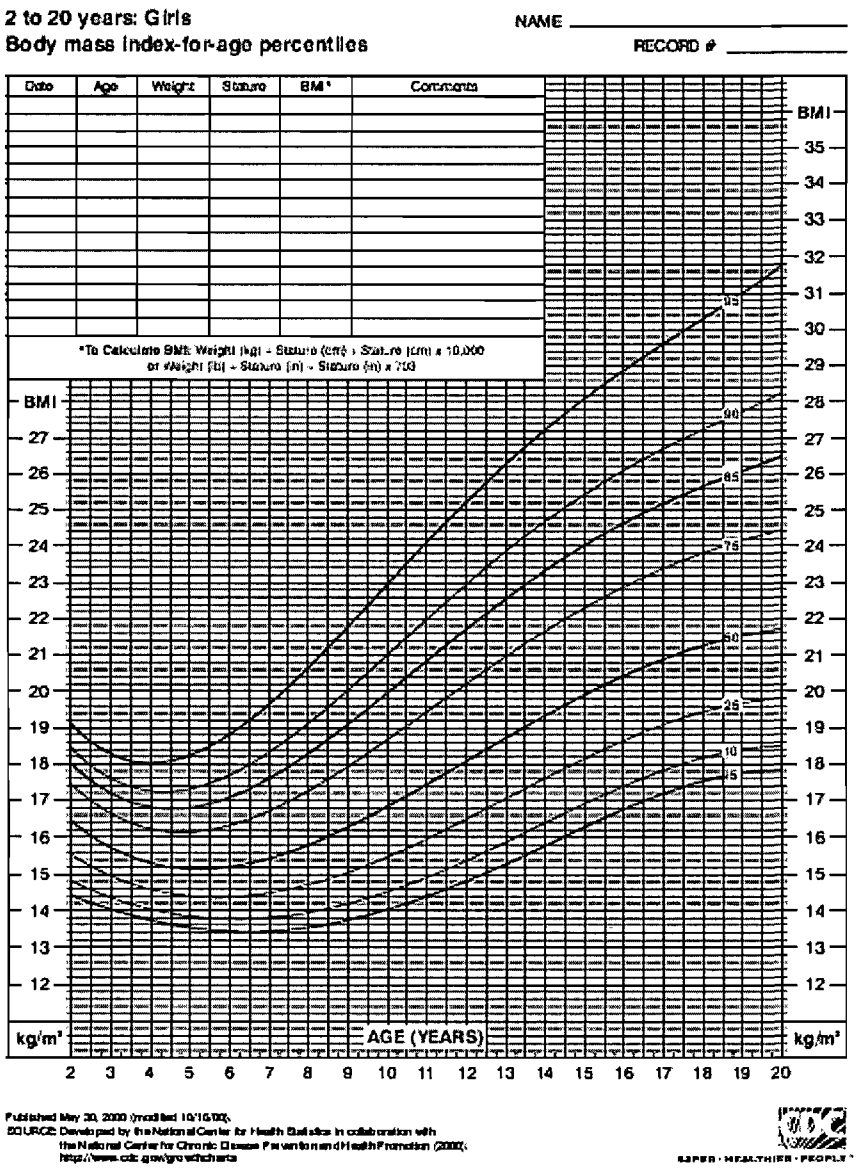

Figure 1. BMI-for-age girls 2 to 20 years

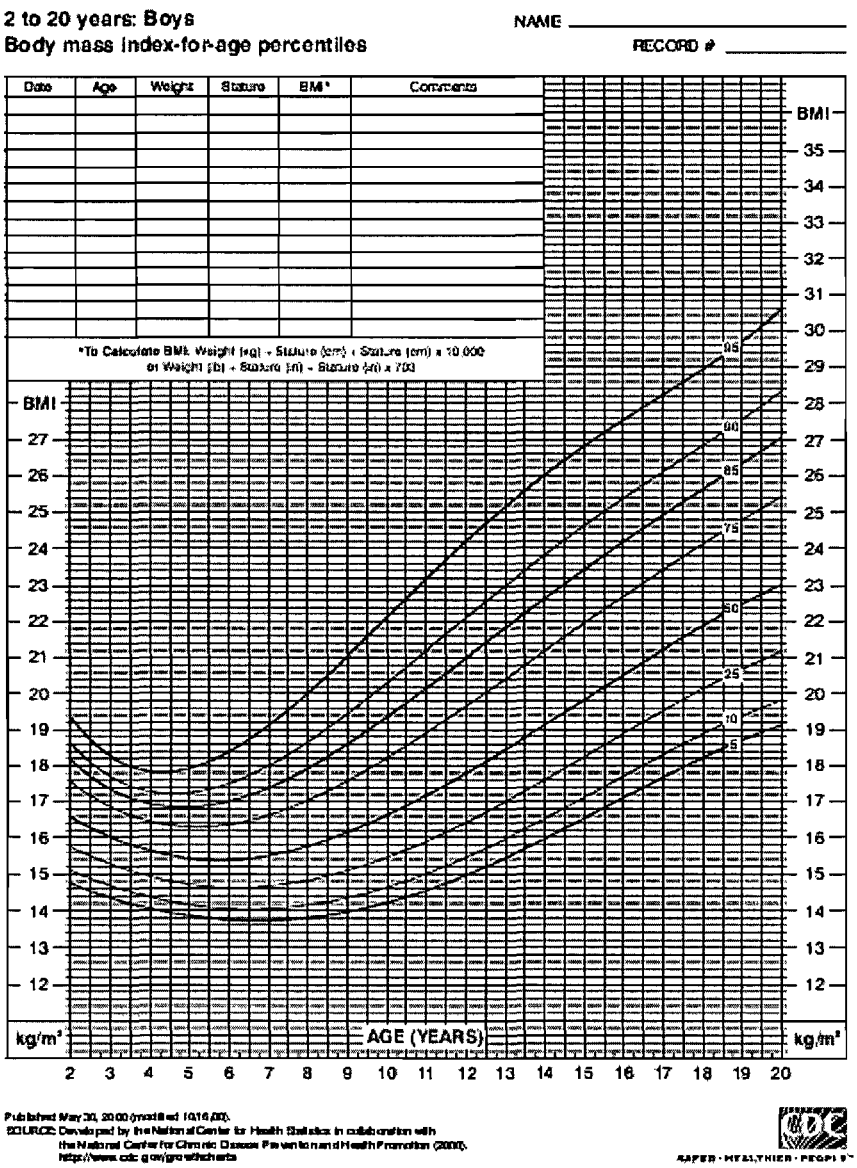

Figure 2. BMI-for-age boys 2 to 20 years

Table III. BMI-for-Age Weight Status Categories and Corresponding Percentiles

Weight Status Category	Percentile Range
Underweight	$< 5^{th}$ percentile
Healthy weight	5^{th} to 84^{th} percentile
Overweight	85^{th} to 94^{th} percentile
Obese	$\geq 95^{th}$ percentile

(Adapted from Barlow 2007)

An additional tool to evaluate obesity is neck circumference. It has been a useful predictor in adults for obesity correlations with apnea, but no appropriate scale has been developed for growing children (Guilleminault 2005).

2.4.7 Upper Airway Obstruction

Any anatomical narrowing in the various parts of the upper airway will have additive effects contributing to SDB. Abnormalities that decrease the radius of the nasal, oral, or pharyngeal airway result in increased airway resistance. Though enlarged tonsils and adenoids contribute greatly to SDB, multiple anatomical obstructions should also be considered (Guilleminault 2005).

2.4.8 Nasal Morphology

Upper respiratory tract pathosis has been associated with OSA. All aspects of the nose should be evaluated for obstruction. Asymmetry of the nares, collapse of the nasal valves during inspiration, a large septal base, septal deviations, turbinate hypertrophy, enlarged adenoids, masses, and polyps are evaluated (Guilleminault 2005). Habitual

mouth breathing may also be a result of nasal occlusion. This is a factor which has been implicated in OSA (Salem 2004).

2.4.9 Craniofacial Morphology

Malformations of the maxilla, mandible and associated structures can also result in upper airway obstruction during sleep. A micrognathic or retrognathic mandible will likely cause the tongue to reduce the pharyngeal airway space and decrease the airflow during sleep. Cleft palate and other craniofacial syndromes have also shown that severe abnormal positioning of the maxillae increases the risk for OSA (Muntz 2008).

2.4.10 Skeletal Morphology

Dimensions of the orofacial skeleton are implicated in pediatric OSA. Extremely reduced airway dimensions due to craniofacial syndromes demonstrate that the maxillae have a significant role to play in the etiology of SDB (Primhak 2005). A high narrow palate, narrow maxilla, posterior crossbites, increased overjet, and dental crowding all demonstrate abnormal maxillomandibular development.

2.4.10.1 Sagittal

Mandibular retrusion has long been a factor associated with OSA (Triplett 1989). Mandibular deficiency impinges on the pharyngeal airway space, thereby increasing posterior airway resistance. Advancing the mandible in children with removable functional appliances decreases the incidence of OSA (Villa 2002). Angle's molar classification as well as the severity of overjet (OJ) will indicate problems relative to maxillary and mandibular length.

Cephalometrics in OSA patients has shown that decreased mandibular length, decreased maxillary length, skeletal retrusion, increased mandibular plane angle (MPA), and low hyoid position have implications in SDB (Kulnis 2000, Lowe 1997). A decreased mandibular body length has a clinically significant association with OSA (Miles 1996). Other studies in children with mild to moderate OSA have demonstrated no association between mandibular dimensions and OSA (Schiffman 2004).

2.4.10.2 Vertical

An increased lower facial third in dolichofacial or long-face patients has been implicated as a risk factor in OSA (Contencin 2003). The mandible is located in a more retruded position in these patients. Also, the mandibular plane is often steeper. Children with long faces, retropositioned mandibles and associated lip incompetence have been shown to have increased sleep-disordered breathing symptoms (Zucconi 1999, Guilleminault 1996). Increased facial dimensions can be measured by facial height proportions (long-face), relative height-to-width proportions (dolichofacial), and increased MPA. Patients are also more prone to having anterior open bites (Salem 2004).

2.4.10.3 Transverse

Maxillary constriction is a sign of reduced transverse dimension of the upper airways. Patients with constricted maxillae have increased nasal resistance which results in increased mouth breathing. An associated low tongue posture may also be present, resulting in posterior airway narrowing (Cistulli 1996). Transverse maxillary deficiency can be clinically assessed. A high narrow palate can be observed. Severe crowding of the maxilla and mandible may also be present. Teeth may be tipped buccally or lingually (Betts 1995). Posterior dental crossbites of two or more permanent teeth can be considered a skeletal crossbite (Jacobs 1980).

2.4.11 Soft Tissue

The intra-oral exam should evaluate the tongue, soft palate, uvula, tonsils and pharyngeal walls as possible causes of obstruction. The evaluation of the oropharynx begins with the relationship between the soft palate, uvula and tongue. The Mallampati (1985) classification, originally developed for evaluation prior to endotracheal intubation, may be a useful scale to assess posterior airway opening. Low lying, thickened palates are a significant finding. The modified Mallampati classification is graded from I to IV depending on the amount of pharyngeal space and soft palate visible when the mouth is opened wide (Friedman 1999).

The tongue should be evaluated relative to its size. Macroglossia is an extrusion of the tongue above the plane of occlusion of the mandible (Waite 1998). An enlarged tongue may impinge on the posterior airway space and be implicated in OSA.

Neuromuscular disease and decreased tonicity of the pharyngeal musculature also predisposes a patient to pharyngeal collapse during inspiration (Amin 2006).

2.4.11.1 Adenotonsillar hypertrophy

Adenoid or tonsillar enlargement is the primary cause of anatomical obstruction in SDB in children (Gozal 1998). The enlargement of these tissues decreases the radius of the nasal and oral airway, thereby increasing airway resistance. This increase in resistance may become clinically significant during nighttime sleep (Sheldon 2001).

The peak of pediatric OSA is thought to occur in the preschool years due to adenotonsillar hypertrophy (Gislasen 1995). Tonsils and adenoids progressively enlarge during childhood and adolescence, followed by a decrease in size during adult life (Vogler 2000, Jeans 1981). Studies have demonstrated that enlarged tonsils and

adenoids are correlated with increased prevalence of OSA, but are not correlated with the severity of OSA (Brooks 1998).

Tonsillar size is graded in relation to the obstruction of the airway (Figure 3). A commonly used scale scores the tonsils, from 0 to 4+, based on the amount of tonsillar pharyngeal obstruction visible from the widest mouth opening (Friedman 1999).

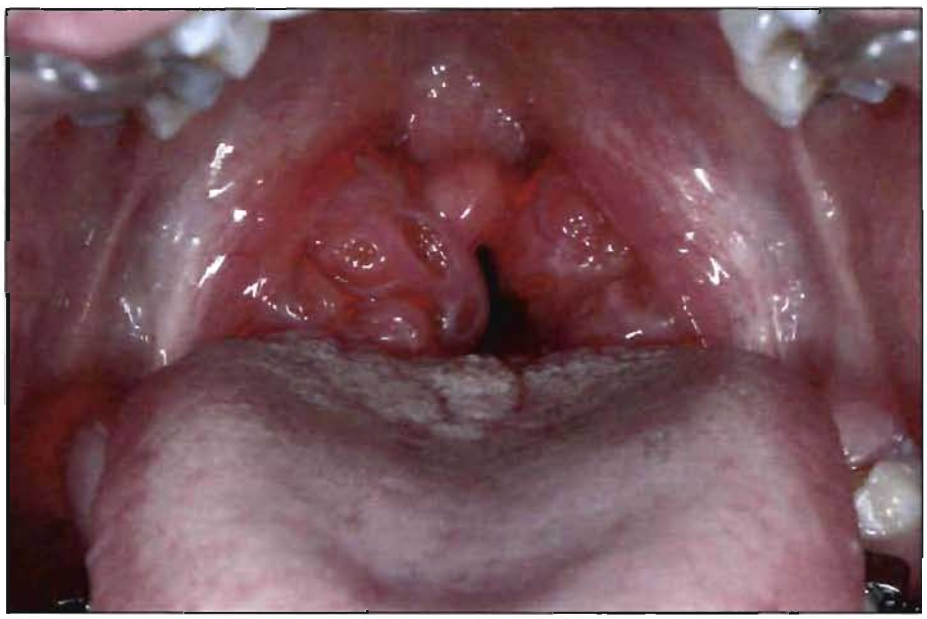

Figure 3. Tonsillar hypertrophy and pharyngeal airway obstruction in an adolescent orthodontic patient

2.5 Consequences of Pediatric Obstructive Sleep Apnea

Overlooking a diagnosis or mismanaging a patient with OSA can have serious consequences (Capdevila 2008). Hypoxemia and increased intrathoracic pressure are associated with cardiopulmonary changes in OSA. Cardiopulmonary dysfunction and excessive daytime somnolence may lead to the most severe consequences of pulmonary

dysfunction and premature death (Waite 1998). Fortunately, mortality due to OSA during childhood is unusual (Sheldon 2001).

Functional and neurocognitive dysfunctions contribute to the significant morbidity of OSA. Excessive daytime sleepiness, hyperactivity, personality changes, and deficits of attention, concentration, psychomotor skills, memory and higher cognitive functions contribute to poor intellectual and social achievement. Developmental delays and depression may also occur (Crabtree 2004, Sheldon 2001). Health-related quality of life is decreased in SDB patients (Rosen 2002). Recent studies also indicate that neuronal brain injury may also occur (Halbower 2006).

If OSA progresses into adulthood, workplace or motor vehicle accidents related to daytime hypersomnolence may lead to severe injury and mortality (Masa 2000). The natural history of OSA eventually results in myocardial ischemia, infarcts, arrhythmias, hypertension, and cerebrovascular accidents. Mortality is increased as the severity of OSA is increased (Partinen 1988).

2.6 Treatment of Sleep-Disordered Breathing

Treatment of pediatric OSA targets the cause of the airway obstruction. The treatment of choice is tonsillectomy and adenoidectomy, as the hypertrophy of these structures is the most common cause of childhood OSA (American Academy of Pediatrics 2002). However, other causes of obstruction may also exist. Treatment options range from behavioural changes to surgical treatment of mandibular advancement, bariatric surgery and tracheostomy.

Multidisciplinary management of OSA should involve respiratory physicians, sleep laboratory technicians, otorhinolaryngologists, oral and maxillofacial surgeons, and orthodontists (Sherring 2001).

The consequences of non-treatment of OSA in childhood may be severe due to the serious long term cardiovascular complications. Developmental processes may also be affected with lasting effects (Nixon 2005).

2.6.1 Behavioural Modification

Changes in sleep position, cessation of depressant medications and decreasing alcohol or drug use aids in preventing OSA. Avoiding sleeping on the back may prevent snoring and anatomical narrowing of the airway. Alcohol and sedatives relax the pharyngeal musculature, reducing airway patency. Their avoidance prior to sleep in adolescents may help decrease SDB symptoms. Allergies can be treated using intranasal steroids, and oral or topical decongestants (Lampasso 2004).

Though difficult to maintain long term, the prevention of obesity and weight control management are also essential during childhood. Not only does it help prevent OSA, but also a host of cardiovascular complications (Barlow 2007).

2.6.2 Continuous Positive Airway Pressure (CPAP)

The gold standard in treatment of OSA in adults is continuous positive airway pressure (CPAP). Nasal CPAP for children has been shown to be an effective and non-invasive treatment. However cooperation and training of the child and family remains the most common impediment to its use (Guilleminault 2005). The benefits of CPAP are decreased daytime sleepiness, fewer arousals, less oxygen desaturation, fewer apneic episodes, reduced hypertension, and improved cognitive function (Marcus 1995).

CPAP has poor compliance due to its side effects which include: mask rash, conjunctivitis, rhinorrhea, sinusitis, congestion, epistaxis, tympanic rupture, pneumothorax, aerophagia, and chest pain (Hoffstein 1992).

Regular reassessments are required in growing children undergoing CPAP treatment. Mask and headgear fit should be evaluated, and attention placed on assessment of any possible maxillary growth restraint (Li 2000).

2.6.3 Oral Appliances

Functional readaptation may be attempted as a part of the treatment of SDB patients. These treatments may aid in enlarging the upper airway. These treatments are amenable to those who have had adenotonsillectomy and present with snoring or mild to moderate OSA, and those who are non-compliant with their CPAP.

2.6.3.1 Mandibular Repositioning Appliances

An increase in posterior airway space is found when using mandibular repositioning appliances (Schmidt-Nowara 1995). Functional appliances which reposition the mandible anteriorly have demonstrated improvement in OSA symptoms (Cozza 2004, Villa 2002, Eveloff 1994). These appliances may be of modified Herbst, monoblock or twin block design. Though these dental and orthodontic procedures may help in the treatment of pediatric OSA, these interventions have not been systematically tested in this population (Sheldon 2001). Questions remain regarding their effectiveness in children (Carvalho 2007).

Side effects of mandibular appliances are changes in occlusion over long periods of time. These appliances require regular monitoring in the growing child. Other reported side effects of these appliances include temporomandibular disorder (TMD) symptoms, extremes of dry mouth or increased salivation, dental pain, and gingival irritation (Pantin 1999).

2.6.3.2 Rapid Palatal Expansion

Rapid palatal expansion (RPE) is a distraction technique which splits the maxilla at its mid-palatal suture. Bone formation then occurs from the cartilage borders to the center of the palate. It is a procedure which is performed in children and adolescents prior to the fusion of the mid-palatal suture. A surgical distraction approach is required post-fusion (Proffit 2007).

Since palatal distraction widens the palate and therefore the floor of the nose, it is postulated that RPE enlarges the nasal orifices by pushing the soft tissues laterally and by decreasing the height of the palate (Pirelli 2004). Recent studies have demonstrated a decrease in OSA resulting from widening of the maxilla and nasal floor. Decreased nasal resistance has also been noted (Villa 2007, Pirelli 2004, Cistulli 1998).

2.6.4 Surgical

Surgical treatment of pediatric OSA is site specific, based on the purported anatomical obstruction and findings of the PSG examination. The gold standard surgical method for treatment of severe OSA is a tracheostomy. This procedure bypasses the entire upper airway and is 100% effective in alleviating OSA. It is, however, reserved for the most severe OSA patients (Sherring 2001). Bariatric or gastric bypass surgery should also be reserved for cases of morbid obesity (Sugerman 2003).

2.6.4.1 Soft Tissue Surgery

Removal of nasal pathology, septoplasty, turbinectomy, soft palate surgery, laser-assisted uvuloplasty (LAUP), uvulo-palatopharyngoplasty (UPPP), and radiofrequency volumetric tissue reduction (RVTR) of the palate may all help in increasing airway patency. Glossectomy, linguloplasty, or RVTR of the tongue base procedures may alter

the tongue volume and position. Most of these procedures are undertaken after the completion of growth and have shown mixed results (Aragon 2001). The most common OSA related surgery in children is the adenotonsillectomy.

2.6.4.2 Adenotonsillectomy

The first treatment approach to be considered in children with OSA is adenotonsillectomy. More airway space is provided regardless of the size of the tonsils and adenoids (Guilleminault 2005). A tonsillectomy or adenoidectomy alone is not as effective as a combined surgery (Guilleminault 2004). Also, a radiofrequency ablation of the inferior nasal turbinates should be considered if these are found to be enlarged.

Traditionally, adenotonsillectomy had been performed in cases of recurrent streptococcal tonsillitis. Recently, a shift has occurred as SDB has become the primary indication for adenotonsillectomy in children (Mitchell 2006). The removal of enlarged tonsils and adenoids has demonstrated a reduction in OSA and an improvement in sleep, daytime behaviour, cognitive function, and quality of life (Montgomery-Downs 2005, Tran 2005, Owens 2000). However, it does not completely eliminate OSA in all patients (Suen 1995). Favourable alterations in facial growth have also been noted in children with OSA after having undergone this procedure (Zettergren-Wijk 2002).

While adenotonsillectomy has been demonstrated to be efficacious in improving symptoms of OSA in children, a Cochrane review of adenotonsillectomy has determined the need for randomized controlled trials to demonstrate this efficaciousness (Lim 2001).

2.6.4.3 Osseous Surgery

Maxillomandibular advancement (MMA) surgery may be indicated in cases unresponsive to less invasive treatment. It is often very successful and should be performed in concert with orthodontic treatment (Aragon 2001). While early treatment in adolescence may be indicated in severe cases, treatment following the completion of growth is preferred (Guilleminault 2005). Mandibular advancement moves the tongue forward and upward by repositioning the anterior digastric, mylohyoid, genioglossus, and geniohyoid muscles. A LeFort I maxillary advancement of 10 to 14mm is accompanied by a corresponding bilateral sagittal split osteotomy of the mandible (Aragon 2001). By stretching the limits of surgical stability with these movements, some degree of relapse is expected despite additional fixation and bone grafting techniques. Prolonged inferior alveolar nerve paresthesia, TMD dysfunction and a weaker bite force are complications that may also occur post surgery (Waite 1998).

Another surgery which advances the tongue is the geniotomy tubercle advancement. This can be performed by advancing a bicortical block of bone through an anterior vestibular incision. The lingual cortical plate is advanced anterior to the labial plate and rotated 90 degrees (Waite 1998). This procedure may provide increased retrolingual space.

Mandibular distraction osteogenesis can be used in young patients for mandibular advancement and anterior tongue displacement with corresponding enlargement of the retrolingual space (Guilleminault 2005). This surgery may be replacing standard mandibular advancement surgeries in children with severe craniofacial abnormalities.

2.7 The Child and Adolescent Orthodontic Patient

Approximately 80% of patients presenting to orthodontic clinics are children and adolescents (Proffit 2007). They present with a variety of esthetic and functional

complaints. Many of these patients have malocclusions which may predispose them to pediatric SDB.

The prevalence of malocclusions in Quebec was assessed in a previous study on 13 and 14 year old schoolchildren (Payette 1989). These results differ to some extent from those reported in a more widely cited National Health and Nutrition Estimates Survey III (NHANES III) from the United States (Proffit 1998).

Anteroposterior maxillary and mandibular dimensions can be assessed using both Angle's molar classification of occlusion and overjet as indicators. In the general Quebec population, it was estimated that 55% were Class I, 31.1% Class II, 12.8% Class III. Severe overjet, measured as being greater than 5mm, was reported to be 18.6% (Payette 1989). The NHANES III study reported a severe overjet of greater than 7mm that was found to be 3.6% of pre-adolescent and adolescent population (Proffit 1998). From this data, it was inferred that 30% had normal Class I occlusion, 50% to 55% had Class I malocclusion, 15% had Class II malocclusion and less than 1% had Class III malocclusion.

Overbite and open bites are measures that can be used to assess the vertical craniofacial dimension. Deep bites of greater than 2/3 incisor overlap were found in 18.4% of children in the Quebec study (Payette 1989). Deep bites above 5mm of overlap were found in 16.8% to 20% of children, between the ages of 8 to 17, in the NHANES III study. Open bites were in the order of 3.5% (Proffit 1998).

The transverse dimension can be assessed by measuring posterior crossbites. Crossbites in the transverse dimension can have the maxillary tooth in a buccal or a lingual relationship to the mandibular tooth. A single tooth crossbite can be considered to be of dental origin and crossbites of two or more permanent teeth tend to be related to skeletal transverse problem (Jacobs 1980). Lingual posterior crossbites were noted in 13.7% of the population in the Quebec Study and between 7.1 and 8.8% in the NHANES III study (Payette 1989, Proffit 1998).

2.8 The Orthodontist's Role in Pediatric OSA

Over the last 20 years, dentists have become more involved in the management of OSA (Bailey 2005). Treatment with oral appliances or oral surgery has allowed dentists to increase their sphere of patient treatment. In addition to participating in patient treatment, the informed dentist is also critical to the early detection of SDB.

The orthodontist has a great opportunity to be involved in the field of sleep medicine, from helping to identify the at-risk patients, to participating in their treatment. However, the dental professional should not treat a patient suffering from SDB without a prior medical evaluation and PSG diagnosis.

The orthodontist should also be aware that different therapies may affect the posterior airway. Most orthodontic therapies will enlarge the posterior airway, but some such as surgical mandibular setbacks and excessive headgear wear may have an opposite effect (Pirilä-Parkkinen 1999).

2.8.1 Diagnosis

Posing a few additional sleep-related questions in the medical questionnaire and considering orofacial and other physical findings from the patient evaluation may help in the detection of patients who may be at-risk of SDB (Magliocca 2005). The orthodontist should look beyond the dentition toward the pharyngeal areas, in order to look for possible areas of obstruction. As a part of every routine examination, an evaluation of the tongue, uvula, soft palate, tonsils and posterior pharynx, as well as the maxillo-mandibular relationships will aid in identifying possible causes of patient-reported sleep problems.

In the orthodontic examination, evaluation of orofacial bone morphology and analysis of the soft tissues may aid in diagnosing patients with reduced airway dimensions. These patients can then be referred to an otolaryngologist or a sleep specialist for additional testing.

2.9 Aims and Hypotheses

As previously stated, the aims of this pilot study are to assess for SDB in a child and adolescent population presenting for orthodontic evaluation at a university clinic. This epidemiological study will identify the prevalence of specific patient morphological characteristics. It will also identify the prevalence of SDB/OSA signs and symptoms in this orthodontic population.

This study will also attempt to demonstrate statistically significant associations between clinical signs of anatomical upper airway obstruction and reported symptoms of OSA. The hypotheses of this study are that there are statistically significant associations between reported symptoms of pediatric OSA and morphological maxillo-mandibular characteristics, specifically:

- Deficiencies in the transverse dimension.
- Deficiencies in the antero-posterior dimension.
- Increased vertical facial height.

The null hypothesis of this study is that there is no relationship between the morphological characteristics and OSA symptoms.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Study Group

This research project is a cross-sectional study design. The sample population was comprised of all patients examined in the screening clinic of the graduate orthodontic program of the Faculty of Dentistry at the Université de Montréal, Montreal, Quebec, Canada. In order to be accepted in the graduate clinic, all patients had completed an application during the previous calendar year. In January, applications were randomly drawn, and screening clinics were held until patient quotas for the following school-year's orthodontic residents were completed. Subjects were recruited for this study between January 2006 and May 2007. The inclusion criteria were:

- Patients who were examined, after having being selected for the screening clinic of the graduate orthodontic program at the Université de Montréal,
- Patients and/or parents/guardians who were able to complete the French-language questionnaires, and
- Patients aged less than 18 years.

The total number of patients screened during this study was 623. The number of non-completed questionnaires was 4. An additional 15 patients were aged 18 years or over and were excluded from the analysis. The final subject study sample consisted of 604 patients.

The project was performed in accordance with institutional ethical norms.

3.2 Questionnaires

The parents or guardians were asked to complete a four-part questionnaire on behalf of their children (See Appendix I). The four parts were: medical and dental history, bruxism and TMD habits, sleep and daytime behaviour, and sleep quantity and quality. The questionnaires were completed by the parent or guardian with the child in the waiting room prior to the orthodontic screening exam. All questionnaires were written in the French language.

3.2.1 Medical and Dental History

Part of the standardized health questionnaire included in the charts of the Orthodontic Section was used for this portion of the study. The reformulated questionnaire consisted of two sections, a medical history and a dental history.

Questions in the medical history portion covered a wide range of medical problems, including hypertension, bleeding problems, frequent colds, pulmonary problems, thyroid disorders, epilepsy, headaches, earaches, allergies, a history of adenotonsillectomy, recent medical visits, and medication use.

Dental history questions included types of dental treatment received, mouth breathing, traumas, dental and gingival pain, history of thumb sucking, tongue and phonetic problems.

3.2.2 Bruxism and TMD Habits

A portion of the standard questionnaire used in the Orofacial Pain and Dysfunction Clinic at the Université de Montreal was reformulated for this study. Various questions were asked regarding daytime and nighttime bruxism (tooth grinding), clenching, and TMD. Questions included articulation dysfunctions, locking of the jaw, mastication

problems, non-nutritive sucking, clenching and grinding teeth, tooth wear, sleep posture, orofacial pain, orofacial muscle fatigue, and eating dysfunction.

3.2.3 Sleep and Daytime Behaviour

The sleep and daytime behaviour portion of the questionnaire was adapted into dichotomous "yes" or "no" type questions from studies of reported symptoms related to SDB. This portion of the questionnaire is a modified and translated version of the 22 item Pediatric Sleep Questionnaire (Chervin 2000). The portion of the questionnaire covered a wide range of sleep and daytime behaviours, including snoring, loud breathing, witnessed cessation of breathing during sleep, mouth breathing, enuresis, daytime fatigue, somnolence, difficulty waking up, obesity, and behavioural problems such as decreased attention span, functional deficits, daytime restlessness, hyperactivity, aggressiveness, and impaired scholastic achievement.

3.2.4 Sleep Quantity and Quality

The final portion of the patient questionnaire was a validated French translation of the Pittsburgh Sleep Quality Index (Blais 1997, Buysse 1989). This questionnaire evaluates quantitative and qualitative sleep parameters. Parameters include: sleep quality, latency, duration, disturbances, medication use, and daytime dysfunction. Observations from someone sharing the same bedroom are also included.

3.3 Clinical Evaluation

The clinical screening evaluation of all of the patients was performed by the same Canadian Board-certified orthodontist (AP). The orthodontist was blinded to the results of the questionnaires. For the screening, patients presented with a recent panoramic

radiograph. The clinical exam consisted of an orthodontic evaluation form with various standard dental, skeletal, functional and esthetic factors. (See Appendix II) A preliminary diagnosis and proposed treatment was formulated at the end of the screening. Patients were measured for height and weight to calculate the BMI [weight in kg / height (m^2)]. Following the clinical examination, the patient and parent or guardian were notified if the patient had or had not been accepted for treatment in the graduate orthodontic clinic.

3.4 Statistics

The analysis for determining the prevalence of various parameters was performed by generating frequency tables for the 604 subjects. Data is presented as the mean ± the standard deviation (SD) for continuous variables and as percentages for categorical variables.

The same data was also used to study associations between the clinical orthodontic exam parameters and reported SDB symptoms. Pearson χ^2 Test and Fisher's Exact Test were used to evaluate the statistical relationships between dichotomous variables. Odds ratios (OR) associated with the presence or absence of characteristics and mean values with 95% confidence intervals (CI) were also calculated. In selected cases with multiple variables, the data was reduced to two categorical groups. Student's *t* tests for independent samples were used to compare samples with continuous data against dichotomous sets.

Statistical significance was assessed at $p < 0.05$; with OR thresholds and associated CI > 1 indicating an aggravating effect, < 1 indicating a protective effect, and = 1 indicating a lack of statistical significance. Data analysis was performed using SPSS (Version 15.0, SPSS Inc., Chicago, Illinois) for Windows software.

RESULTS

4. RESULTS

4.1 Patient Characteristics

The total number of patients screened in the graduate orthodontic clinic at the Université de Montréal over 17 months was 623. Of this number, 4 were excluded due to non-completed questionnaires and an additional 15 patients did not meet the inclusion criteria as they were aged 18 years or over. The final subject study sample consisted of 604 patients.

The assessment form for the screening exam was completed by the same orthodontist performing the exam who was blinded to the results of the patient questionnaire. The parents/guardians completed the questionnaires with their children or adolescents in the waiting room prior to their being admitted to the screening exam.

The results obtained in this study can be described in two sections. The first section describes the study population in terms of its demographics, and in terms of the prevalence of malocclusions, medical problems, parafunctional habits, and SDB characteristics. The second section describes the statistical relationships between potential associations of signs of upper airway obstruction and symptoms of OSA from the pediatric sleep questionnaire. The examined morphological traits, reported medical, and parafunctional problems and habits were all statistically compared to common symptoms of SDB.

4.1.1 Population

The six hundred and four children and adolescents in the study sample had a mean age of 13.01 (SD=2.28) (See Table IV). The sex distribution was 55.5% female and 45.5%

male. The majority of the patients were Caucasian (82.4%), with the next largest population being of African origin at 8.0%.

BMI categories were determined by calculating the patient BMI and comparing this value to the sex-specific CDC BMI-for-Age growth charts (Figures 1 and 2). A percentile value was obtained for each subject and converted into a specific category according to the method in Table III. The BMI scores indicated that 77.6% of the sample was considered to be a healthy weight or underweight and 22.4% were considered overweight or obese.

Table IV. Demographic Data of Study Group

Variable		
Age	(years)	13.01 ± 2.28
	Range	7.83-17.83
Sex	(male / female)	44.5% / 55.5%
Ethnic origin	Caucasian	82.4%
	African	8.0%
	Hispanic	6.8%
	Asian	2.8%
BMI categories	Underweight	2.7%
	Healthy weight	74.9%
	Overweight	14.2%
	Obese	8.2%

4.1.2 Orthodontic Evaluation

The orthodontic screening examination results of the study group are found in Table V. The majority of patients were found to have mesofacial morphologies (71.4%) and convex profiles (86.4%). Dolichofacial or long-face morphology was noted in 15.7% of patients. A narrow palate was identified in 8.4% of subjects. Posterior crossbites involving two or more teeth were found in 10.4% of the subjects. Most patients were assessed as skeletal Class I (59.2%) and dental molar Class I (51.2%). The remainder of the patients were mostly Class II (skeletal: 35.4%, dental: 43.7%). There were few Class III patients in both the skeletal (5.4%) and dental (5.1%) categories.

Dental parameters were also assessed during the screening. Overbite and overjet were measured. The average incisor overbite (OB) was found to be 3.76 mm (SD = 1.99). Of these, 2.2% had anterior open bites (OB < 0). The average incisor overjet (OJ) was 4.28 mm (SD = 2.68). Severe OJ greater than or equal to 7 mm was found in 18.4% of subjects. Maxillary and mandibular dental crowding was assessed on a scale ranging from spacing to severe crowding. Severe maxillary and mandibular dental crowding requiring over 5 mm of additional arch space was found in 16.1% of cases.

Functional features subjectively assessed during the screening were tongue size, tonsil size, and breathing pattern. Enlarged tonsils were observed in 17.3% of patients. A large tongue was noted only in 0.7%, though fissured or scrotal tongue was seen in 8.2%. Primary mouth breathing was assessed in 21.5% of patients, with the remainder being primarily nose breathers (46.3%), followed by mixed nose-mouth breathers (32.3%).

Table V. Morphological Data from the Orthodontic Evaluation

Category	Feature		
Vertical Dimension	Facial Type	Brachyfacial	12.9%
		Mesofacial	71.4%
		Dolichofacial	15.7%
	Facial Height	Decreased	19.7%
		Normal	70.2%
		Increased	10.1%
	Mandibular Plane Angle	Low	12.6%
		Normal	71.7%
		High	15.7%
	Incisor Overbite		3.76 ± 1.99 mm
Transverse Dimension	Maxillary Width	Decreased	25.2%
		Normal	74.5%
		Increased	0.3%
	Palatal Form	Narrow	8.4%
		Round	91.6%
		Flat	0%
	Posterior Crossbite		10.4%
Sagittal Dimension	Facial Profile	Convex	86.4%
		Straight	13.2%
		Concave	0.3%
	Mandibular Position	Retrusive	23.7%
		Normal	72.7%
		Protrusive	3.6%
	Skeletal Diagnosis	Class I	59.2%
		Class II	35.4%
		Class III	5.4%
	Dental Diagnosis	Class I	51.2%
		Class II	43.7%
		Class III	5.1%
	Incisor Overjet		4.28 ± 2.68 mm

Table V. Morphological Data from the Orthodontic Evaluation (continued)

Category	Feature		
Dental Arch	Maxillary Crowding	Spacing	12.6%
		Mild	50.0%
		Moderate	21.4%
		Severe	16.1%
	Mandibular Crowding	Spacing	7.6%
		Mild	57.1%
		Moderate	19.2%
		Severe	16.1%
Functional	Tonsil Size	Normal	82.7%
		Enlarged	17.3%
	Tongue Size	Small	0.3%
		Normal	90.8%
		Enlarged	0.7%
		Fissured	8.2%
	Breathing	Mouth	21.5%
		Nose	46.3%
		Mouth & Nose	32.3%

4.1.3 Medical and Dental History

Prevalence data obtained from the standardized medical and dental questionnaire is found in Table VI. One quarter (25.1%) of subjects had reported allergies. A low percentage of patients (< 3%) reported frequent colds or sinusitis and pulmonary problems. Frequent headaches were reported in 3.8% of subjects. Previous adenoidectomy or tonsillectomy was reported for 12.8% of patients.

The use of regular medications was described in 11.5% of patients, with 6.1% of all patients reporting use of psychostimulant medications. Bronchodilators were taken by 1.5% of patients.

Breathing pattern was reported as assessed by the parents. Predominant mouth breathing was reported in 12.2% of subjects. Mixed nose-mouth breathers were reported as 53.0% of the group and predominant nose breathing accounted for the rest (31.9%).

Oral habits were also considered. A positive history of a thumb or finger sucking habit was reported in 17.1% of patients. One percent of all patients were described as continuing this habit.

Table VI. Reported Medical and Dental History Data from the Patient Questionnaire

Category	Feature	
Medical Problems	Allergies	25.1%
	• Hay Fever	9.3%
	• Asthma	9.3%
	• Dust Allergy	7.8%
	• Animal Dander	8.0%
	• Other (Food, Medications)	11.8%
	Frequent Colds or Sinusitis	2.8%
	Pulmonary Problems	2.2%
	Frequent Headaches	3.8%
Medical Treatments	Regular Medication Use	11.5%
	• Psychostimulants	6.1%
	• Bronchodilators	1.5%
	Adenotonsillectomy Surgery	12.8%
	Previous Speech Pathologist Consultation	15.9%
Breathing	Mouth Breathing	12.2%
	Nose Breathing	31.9%
	Mouth & Nose Breathing	53.0%
Habits	Previous Thumb/Finger Sucking	17.1%
	Continued Thumb/Finger Sucking	1.0%

4.1.4 Bruxism and TMD Habits

Orofacial pain and dysfunction were assessed in one section of the questionnaire. Reported prevalence data is found in Table VII. Less than five percent prevalence was reported for most TMD or myofascial pain symptoms; however, according to the questionnaire 16.3% of patients clenched their teeth and 12.0% reported grinding their teeth (bruxism).

Table VII. Reported Bruxism and TMD Habits from the Patient Questionnaire

Category	Feature	
TMD	Clicking Sound on Opening/Closing	4.3%
	Crepitus on Opening/Closing	3.0%
	Closed Lock	2.2%
	Open Lock	1.2%
Parafunction	Clenching Teeth	16.3%
	Bruxism	12.0%
	Mandibular Soreness on Awakening	4.8%
	Facial/Masticatory Muscle Pain	5.1%

4.1.5 Sleep and Daytime Behaviour

The prevalence data for the sleep questionnaire assessing pediatric OSA symptoms is found in Table VIII. Patients reported as usual snorers were 10.9%. Those reported to breathe heavily or loudly during sleep were 17.7%, and loud snorers were noted in 5.3%. Those having troubled breathing during sleep were 5.1%; however, observed apneas were noted in 1.8% of patients. Mouth breathing during the day was reported in 34.0% of subjects. Patients having dry mouths when waking up in the morning were 36.1%.

Patients waking up, yet feeling unrefreshed were 20.6% of the subjects. Daytime sleepiness was reported in 7.3%, with 3.3% of all parents having been told by a teacher or someone else that the patient had a sleepiness problem during the day.

Behavioural problems ranged from being agitated (7.7%) to easily distracted (26.7%). Reported obesity was 2.2% and those having difficulty in school was 8.2%

Table VIII. Reported Sleep and Daytime Behaviour Data from the Patient Questionnaire

Category	Feature	
Snoring Frequency	Usually Snores	10.9%
	Always Snores	2.9%
Snoring Quality	Snores Loudly	5.3%
	Heavy or Loud Breathing	17.7%
Breathing Problems	Trouble Breathing During Sleep	5.1%
	Stop Breathing During the Night	1.8%
Mouth Breathing	Daytime Mouth Breathing	34.0%
	Dry Mouth on Awakening	36.1%
Daytime Sleepiness	Feeling Unrefreshed in Morning	20.6%
	Problem with Somnolence	7.3%
	Sleepy as Reported by a Teacher	3.3%
	Difficult to Awaken in Morning	23.6%
Inattention/Hyperactivity	Does Not Seem to Listen When Spoken To	15.0%
	Difficulty Organizing Tasks and Activities	12.5%
	Easily Distracted by External Stimuli	26.7%
	Fidgets with Hands or Feet	21.5%
	Agitated	7.7%
	Interrupts or Intrudes on Others	11.8%
	Poor Scholastic Results	8.2%
Other Symptoms	Occasionally Wets the Bed	4.8%
	Morning Headache	3.5%
	Delayed Growth Period Since Birth	16.7%
	Obesity	2.2%

4.1.6 Sleep Quantity and Quality

Quantitative and qualitative sleep parameters were reported in the final questionnaire section. The results are found in Table IX.

The total hours of sleep during the past month for the subjects were reported to be an average of 9:08:23 hours (SD = 0:59:42). The reported hours of sleep ranged between 5.5 hours and 12.5 hours. The average amount of time before falling asleep was reported as being 20:29 minutes (SD = 15:40). The reported range was between 0 minutes and 120 minutes. Increased time to fall asleep was described in 10.7% of patients who had been unable to fall asleep within 30 minutes at least 3 times per week. Poor overall sleep quality was described in 3.9% of patients.

Table IX. Reported Sleep Quantity and Quality During the Past Month from the Patient Questionnaire

Category	Feature		
Sleep Quantity	Unable to Fall Asleep Within 30min ≥ 3X/Week		10.7%
	Average Minutes Before Falling Asleep		20:29 min ± 15:40
		Range	0:00-120:00
	Average Hours of Sleep Per Night		9:08:23 h ± 0:59:42
		Range	5:50:00-12:50:00
Sleep Quality	Poor Overall Sleep Quality		3.9%

4.2 Statistical Associations of SDB Symptoms

The data from the screening assessment form and certain multiple-scaled questions from the patient questionnaire were regrouped for dichotomous variable analysis. The most severe morphological trait in each category implicated in upper airway obstruction in SDB was retained, and the other variables were regrouped to facilitate statistical analysis. A summary of the statistically significant associations of the examined morphological and functional features compared to pediatric OSA symptoms (Tables XII to XXVII) is found in Table X. A summary between the reported health-related patient features compared to pediatric OSA symptoms (Tables XXVIII to XL) is found in Table XI.

Table X. Summary of Statistical Associations Between Evaluated Patient Morphological and Functional Features and Pediatric OSA Symptoms

		Vertical				Transverse			Sagittal				Arch		Functional		
		Dolichofacial	Long Face	High MPA	Open Bite	Decreased width	Narrow Palate	Posterior X-Bite	Retrusive Mandible	Class II Skeletal	Class II Dental	Severe Overjet	Severe Mx Crowd	Severe Mand Crowd	Large Tonsils	Large Tongue	Mouth Breathe
Snoring	Usually Snores	**	-	**	-	-	*TR*	-	-	-	-	-	***	***	*TR*	-	**
	Always Snores	-	-	-	-	-	*	*TR*	-	-	-	-	**	**	-	-	*TR*
	Snores Loudly	***	-	***	-	**	***	**	-	-	-	-	***	***	*	-	***
	Heavy Breathing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	***
Breathing	Trouble Breathing	*	-	*	-	*	*TR*	-	-	-	-	-	-	-	-	-	**
	Observed Apneas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Day Mouth Breathing	***	*TR*	***	-	*	**	-	-	-	-	-	-	*	-	-	***
	Dry Mouth on Awakening	**	*	***	-	-	**	-	-	-	-	-	***	**	-	-	***
Daytime Sleepiness	Unrefreshed in Morning	-	-	-	-	-	***	-	-	-	-	-	*TR*	*TR*	-	-	*TR*
	Somnolence	*	-	*	-	-	***	-	-	-	-	-	*TR*	-	-	-	-
	Sleepy Per Teacher	-	-	-	-	*TR*	**	-	-	-	-	-	**	-	-	-	***
	Difficult to Awake	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Inattention/ Hyperactivity	Does Not Listen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*TR*
	Difficulty Organizing	-	-	-	-	-	-	-	-	*TR*	-	-	-	-	-	-	-
	Easily Distracted	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
	Fidgets	-	-	-	-	-	*TR*	-	-	-	-	-	-	-	-	-	*TR*
	Agitated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Interrupts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Poor Scholastic Results	-	-	-	-	-	-	-	-	*	*	**	-	-	-	-	-
Other Symptoms	Nocturnal Enuresis	-	-	-	-	Inv	-	-	Inv	-	-	-	-	-	-	-	-
	Morning Headache	-	-	-	-	-	*	-	*TR*	*	*	*TR*	-	-	-	-	-
	Delayed Growth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Obesity	-	-	-	-	*	-	*	-	-	-	-	-	-	-	**	-
	Bruxism	-	-	-	-	-	-	-	*TR*	**	*	*TR*	-	-	-	-	-
	Clenching Teeth	-	-	-	-	-	-	-	*TR*	-	-	-	Inv	Inv	Inv	*	-
Sleep	Difficulty Initiating Sleep	*	-	*	-	-	-	-	Inv	Inv	-	-	-	-	-	-	-
	Fewer Hours of Sleep	-	-	-	*TR*	-	*	-	Inv	Inv	Inv	Inv	**	*	-	-	Inv
	Poor Sleep Quality	-	-	-	-	-	**	-	-	-	-	-	*	-	-	-	*

Abbreviations: Aggravating relationship: *TR* (trend – nearly significant) $P < 0.1$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$
Protective relationship: Inv (inversely significant relationship) $P < 0.05$

Table XI. Summary of Statistical Associations Between Reported Patient Health-Related Features and Pediatric OSA Symptoms

		Breathing		BMI		Allergies			Treatments			Other		
		Mouth Breathing	Day Mouth Breathing	Overweight/Obese	Obese	Allergies	Frequent Colds	Pulmonary Problems	Adenotonsillectomy	Bronchodilator	Psychostimulants	Frequent Headaches	Bruxism	Thumb Sucking Hx
Snoring	Usually Snores	***	***	-	-	-	-	-	-	-	-	-	-	-
	Always Snores	-	*	-	-	-	-	-	-	-	-	-	-	-
	Snores Loudly	***	***	-	*TR*	-	-	-	-	-	-	-	-	-
	Heavy Breathing	***	***	-	*	*	-	**	-	*	-	-	-	**
Breathing	Trouble Breathing	***	***	-	-	**	*	**	-	**	-	-	-	-
	Observed Apneas	-	*TR*	-	-	-	-	-	Inv	-	-	-	-	-
	Day Mouth Breathing	***		-	-	-	**	-	-	-	-	-	-	-
	Dry Mouth on Awakening	***	***	-	-	-	-	-	-	-	-	-	*TR*	-
Daytime Sleepiness	Unrefreshed in Morning	*TR*	***	Inv	Inv	*	*TR*	-	-	-	-	***	-	*
	Somnolence	-	*TR*	Inv	Inv	-	***	-	-	-	-	**	-	-
	Sleepy Per Teacher	*	-	-	-	-	**	-	-	-	-	-	-	-
	Difficult to Awake	*TR*	*	-	-	*	**	-	-	-	-	**	*TR*	*TR*
Inattention/ Hyperactivity	Does Not Listen	*	**	-	-	-	-	-	-	-	*TR*	-	*TR*	-
	Difficulty Organizing	-	-	-	-	*TR*	-	-	-	-	***	-	*TR*	-
	Easily Distracted	-	***	Inv	Inv	-	*TR*	-	-	-	***	*	-	-
	Fidgets	-	***	Inv	-	**	*	-	-	-	*TR*	-	-	-
	Agitated	-	***	-	-	-	-	-	-	-	*	*TR*	-	-
	Interrupts	*TR*	**	-	-	*	**	*TR*	-	-	-	-	-	-
	Poor Scholastic Results	-	-	-	-	-	*TR*	-	-	-	-	-	-	-
Other Symptoms	Nocturnal Enuresis	-	-	-	-	-	-	-	-	-	-	-	-	-
	Morning Headache	-	-	-	-	-	-	-	-	-	-	***	-	*TR*
	Delayed Growth	-	-	-	-	-	-	-	**	-	-	-	Inv	-
	Obesity	-	*	***	***	-	-	-	-	-	-	-	-	*
	Bruxism	-	-	-	-	-	-	-	-	-	*TR*	-		-
	Clenching Teeth	-	*TR*	-	-	*TR*	-	-	-	-	-	-	***	-
Sleep	Difficulty Initiating Sleep	-	-	-	-	*	-	-	-	-	-	-	-	-
	Fewer Hours of Sleep	-	-	-	-	-	-	-	-	-	-	-	Inv	-
	Poor Sleep Quality	-	*	-	-	*	-	-	-	-	-	**	-	-

Abbreviations: Aggravating relationship: *TR* (trend – nearly significant) $P < 0.1$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$
Protective relationship: Inv (inversely significant relationship) $P < 0.05$

4.2.1 Craniofacial Morphology

A number of skeletal and dental morphological traits were examined and could be categorized into factors relating to upper airway obstruction. Three are related to the vertical, transverse and sagittal skeletal planes of assessment, while the fourth is related to the shape and dimensions of the dento-alveolar arch.

4.2.1.1 Vertical Excess

Four morphological traits from the clinical exam were related to an increase in vertical facial dimensions. These traits were dolichofacial morphology, increased facial height, a high mandibular plane angle (MPA), and an anterior open bite. Statistically significant relationships were found between these and a number of variables associated with pediatric OSA (Tables XII to XV). The dolichofacial and high MPA characteristics demonstrated statistical significance with several snoring and breathing symptoms, as well as daytime somnolence. A positive association was also found between these long-face traits and increased time taken to fall asleep. Few associations between pediatric OSA traits and those of anterior open bites and a vertically long face were statistically significant.

Table XII. Statistical Associations Between Evaluated Facial Morphology and Reported Pediatric OSA Symptoms

	Dolichofacial	Mesofacial & Brachyfacial	OR (95% CI)	*P-value*
Usually Snores	19.8%	9.4%	2.4(1.3-4.3)	0.006
Snores Loudly	14.3%	3.7%	4.4(2.1-9.3)	<0.001
Trouble Breathing	9.8%	4.1%	2.6(1.1-5.8)	0.033
Day Mouth Breathing	50.0%	31.3%	2.2(1.4-3.4)	0.001
Dry Mouth on Awakening	48.4%	33.9%	1.8(1.2-2.9)	0.010
Somnolence	13.8%	6.2%	2.4(1.2-4.8)	0.016
Difficulty Initiating Sleep	24:10min(SD15:53)	19:54min(SD15:38)	-	0.018

Table XIII. Statistical Associations Between Evaluated Long Face Morphology and Reported Pediatric OSA Symptoms

	Long Face	Normal & Short Face	OR (95% CI)	*P-value*
Day Mouth Breathing	*44.3%*	*32.8%*	*1.6(0.9-2.8)*	*0.087*
Dry Mouth on Awakening	49.2%	34.6%	1.8(1.1-3.1)	0.034

Italics denote a statistical trend (P < 0.1)

Table XIV. Statistical Associations Between Evaluated MPA and Reported Pediatric OSA Symptoms

	High MPA	Normal & Low MPA	OR (95% CI)	*P-value*
Usually Snores	19.8%	9.4%	2.4(1.3-4.3)	0.006
Snores Loudly	14.4%	3.7%	4.4(2.1-9.4)	<0.001
Trouble Breathing	9.9%	4.1%	2.6(1.1-5.9)	0.031
Day Mouth Breathing	53.2%	30.7%	2.6(1.6-4.0)	<0.001
Dry Mouth on Awakening	52.7%	33.1%	2.2(1.4-3.5)	<0.001
Somnolence	13.8%	6.2%	2.4(1.2-4.8)	0.016
Difficulty Initiating Sleep	23:40min(SD15:53)	19:59min(SD15:39)	-	0.041

Table XV. Statistical Associations Between Evaluated Open Bites and Reported Pediatric OSA Symptoms

	Open Bite	Positive Overbite	OR (95% CI)	*P-value*
Fewer Hours of Sleep	*8:37:30h(SD0:43:15)*	*9:09:03h(SD0:59:51)*	-	*0.062*

Italics denote a statistical trend (P < 0.1)

4.2.1.2 Transverse Maxillary Deficiency

The assessment of the palatal morphology was positively associated with 10 of the 28 pediatric OSA symptoms. (Table XVII) Snoring, mouth breathing, daytime sleepiness, decreased sleep, poorer quality sleep, and morning headache were significantly

associated with a narrow palate. The association between a posterior crossbite was only shown to be statistically significant with reported obesity and loud snoring. (Table XVIII) A decreased maxillary width was also related to obesity and loud snoring, but also to troubled breathing and mouth breathing. (Table XVI) A protective effect was found with nocturnal enuresis, where a statistically significant relationship was discovered between nighttime bed wetting and normal or increased palatal width.

Table XVI. Statistical Associations Between Evaluated Maxillary Width and Reported Pediatric OSA Symptoms

	Decreased Width	**Normal & Increased Width**	**OR (95% CI)**	***P-value***
Snores Loudly	10.6%	3.4%	3.3(1.6-6.9)	0.002
Trouble Breathing	8.7%	3.9%	2.4(1.1-5.0)	0.030
Day Mouth Breathing	41.1%	31.6%	1.5(1.03-2.2)	0.037
Sleepy Per Teacher	*6.0%*	*2.5%*	*2.5(1.0-6.2)*	*0.062*
Nocturnal Enuresis	1.3%	6.0%	0.2(0.05-0.9)	0.016
Obesity	4.6%	1.3%	3.6(1.2-10.9)	0.023

Italics denote a statistical trend ($P < 0.1$)

Table XVII. Statistical Associations Between Evaluated Palatal Morphology and Reported Pediatric OSA Symptoms

	Narrow Palate	Round & Flat Palate	OR (95% CI)	*P-value*
Usually Snores	*20.0%*	*10.1%*	*2.2(1.0-4.7)*	*0.053*
Always Snores	8.2%	2.4%	3.6(1.1-11.5)	0.045
Snores Loudly	18.0%	4.1%	5.1(2.2-11.9)	0.001
Trouble Breathing	*10.2%*	*4.6%*	*2.4(0.9-6.4)*	*0.093*
Day Mouth Breathing	52.0%	32.4%	2.3(1.3-4.1)	0.007
Dry Mouth on Awakening	56.0%	34.2%	2.4(1.4-4.4)	0.003
Unrefreshed in Morning	46.0%	18.3%	3.8(2.1-6.9)	<0.001
Somnolence	22.0%	6.0%	4.4(2.1-9.4)	<0.001
Sleepy Per Teacher	12.0%	2.6%	5.2(1.9-14.2)	0.004
Fidgets	*32.0%*	*20.5%*	*1.8(1.0-3.4)*	*0.071*
Morning Headache	10.0%	2.9%	3.7(1.3-10.6)	0.024
Poor Sleep Quality	12.2%	3.1%	4.4(1.6-11.6)	0.008
Fewer Hours of Sleep	8:40:12h(SD1:00:43)	9:01:12h(SD1:00:20)	-	0.019

Italics denote a statistical trend (P < 0.1)

Table XVIII. Statistical Associations Between Evaluated Maxillary Posterior Crossbites and Reported Pediatric OSA Symptoms

	Posterior Crossbite	No Posterior Crossbite	OR (95% CI)	*P-value*
Always Snores	*6.6%*	*2.5%*	*2.7(0.9-8.7)*	*0.091*
Snores Loudly	14.5%	4.2%	3.8(1.6-7.1)	0.003
Obesity	6.5%	1.7%	4.0(1.2-13.4)	0.037

Italics denote a statistical trend (P < 0.1)

4.2.1.3 Sagittal Mandibular Deficiency

Antero-posterior deficiencies were not found to be highly associated with reported pediatric OSA symptoms. (Tables XIX to XII) Snoring, breathing, and sleepiness problems were not significantly associated with the measures of mandibular deficiency. Poor scholastic results were significantly associated with Class II skeletal and dental

relationships, as well as severe overjet. Presence of morning headaches and bruxism were also significantly associated to both Class II relationships.

A protective statistically significant relationship was also found between having a retrusive mandible and nocturnal enuresis. T-tests demonstrated significant protective associations between mandibular deficiency traits and decreased time to get to sleep, as well as with increased sleeping time.

Table XIX. Statistical Associations Between Evaluated Mandibular Deficiency and Reported Pediatric OSA Symptoms

	Retrusive Mandible	Normal & Prognathic Mandible	OR (95% CI)	*P-value*
Nocturnal Enuresis	1.4%	5.9%	0.2(0.05-0.98)	0.040
Morning Headache	*6.3%*	*2.6%*	*2.5(1.0-6.1)*	*0.062*
Bruxism	*16.9%*	*10.5%*	*1.7(1.0-3.0)*	*0.054*
Clenching Teeth	*21.1%*	*14.8%*	*1.5(1.0-2.5)*	*0.090*
Difficulty Initiating Sleep	18:24min(SD12:54)	21:06min(SD16:23)	-	0.045
Fewer Hours of Sleep	9:05:03h(SD1:00:37)	9:19:38h(SD0:55:17)	-	0.013

Italics denote a statistical trend (P < 0.1)

Table XX. Statistical Associations Between Evaluated Skeletal Classification and Reported Pediatric OSA Symptoms

	Class II Skeletal	Class I & III Skeletal	OR (95% CI)	*P-value*
Difficulty Organizing	*16.4%*	*10.9%*	*1.6(1.0-2.6)*	*0.070*
Poor Scholastic Results	12.1%	6.1%	2.1(1.1-4.0)	0.026
Morning Headache	5.3%	2.1%	2.6(1.03-6.6)	0.049
Bruxism	17.5%	8.7%	2.2(1.3-3.7)	0.003
Difficulty Initiating Sleep	18:12min(SD13:10)	21:23min(SD15:51)	-	0.015
Fewer Hours of Sleep	9:19:19h(SD0:55:20)	9:01:36h(SD1:01:17)	-	0.001

Italics denote a statistical trend (P < 0.1)

Table XXI. Statistical Associations Between Evaluated Dental Classification and Reported Pediatric OSA Symptoms

	Class II Dental	Class I & III Dental	OR (95% CI)	*P-value*
Poor Scholastic Results	11.2%	6.0%	2.0(1.03-3.8)	0.047
Morning Headache	5.3%	2.1%	2.7(1.1-6.8)	0.042
Bruxism	15.7%	9.1%	1.9(1.1-3.0)	0.016
Fewer Hours of Sleep	9:16:50h(SD0:56:00)	9:02:00h(SD1:01:41)	-	0.003

Table XXII. Statistical Associations Between Evaluated Incisor Overjet and Reported Pediatric OSA Symptoms

	Severe Overjet ≥ 7mm	Overjet < 7mm	OR (95% CI)	*P-value*
Poor Scholastic Results	16.1%	6.6%	2.7(1.4-5.5)	0.008
Morning Headache	*6.3%*	*2.9%*	*2.3(0.9-5.8)*	*0.085*
Bruxism	*17.1%*	*10.8%*	*1.7(1.0-3.0)*	*0.075*
Fewer Hours of Sleep	9:20:53h(SD0:58:27)	9:05:41h(SD0:59:41)	-	0.018

Italics denote a statistical trend (P < 0.1)

4.2.1.4 Dental Arch Deficiency

Maxillary and mandibular dental crowding was assessed on a scale from spacing to severe crowding. Severe crowding was assessed when compared to all subjects who did not have severe crowding. Severe crowding in the maxilla and mandible was significantly associated with increased snoring, loud snoring, dry mouth on awakening, and fewer hours of sleep. (Tables XXIII and XXIV) Severe maxillary crowding was significantly related with poor sleep quality and teacher reports of daytime somnolence. Severe mandibular crowding and daytime mouth breathing were found to have a statistically significant relationship.

Subjects who were reported to clench their teeth were found not to have severe maxillary or mandibular crowding. These protective relationships were statistically significant.

Table XXIII. Statistical Associations Between Evaluated Maxillary Dental Crowding and Reported Pediatric OSA Symptoms

	Severe Maxillary Crowding	Non-Severe Maxillary Crowding	OR (95% CI)	*P-value*
Usually Snores	22.7%	8.6%	3.1(1.8-5.5)	<0.001
Always Snores	8.5%	1.8%	5.0(1.9-13.3)	0.002
Snores Loudly	14.9%	3.4%	4.9(2.3-10.3)	<0.001
Dry Mouth on Awakening	51.5%	33.1%	2.1(1.4-3.3)	0.001
Unrefreshed in Morning	*27.8%*	*19.2%*	*1.6(0.9-2.7)*	*0.074*
Somnolence	*12.4%*	*6.4%*	*2.1(1.0-4.2)*	*0.053*
Sleepy Per Teacher	8.2%	2.4%	3.7(1.5-9.2)	0.008
Clenching Teeth	8.2%	17.8%	0.4(0.2-0.9)	0.017
Poor Sleep Quality	8.5%	3.0%	3.0(1.2-7.4)	0.018
Fewer Hours of Sleep	8:43:45h(SD0:59:19)	9:02:27h(SD1:00:26)	-	0.006

Italics denote a statistical trend (P < 0.1)

Table XXIV. Statistical Associations Between Evaluated Mandibular Dental Crowding and Reported Pediatric OSA Symptoms

	Severe Mandibular Crowding	Non-Severe Mandibular Crowding	OR (95% CI)	*P-value*
Usually Snores	21.6%	8.8%	2.9(1.6-5.1)	0.001
Always Snores	8.5%	1.8%	5.0(1.9-13.3)	0.002
Snores Loudly	14.9%	3.4%	4.9(2.3-10.3)	<0.001
Day Mouth Breathing	43.3%	32.2%	1.6(1.03-2.5)	0.046
Dry Mouth on Awakening	48.5%	33.7%	1.9(1.2-2.9)	0.008
Unrefreshed in Morning	*27.8%*	*19.2%*	*1.6(1.0-2.7)*	*0.074*
Clenching Teeth	8.2%	17.8%	0.4(0.2-0.9)	0.017
Fewer Hours of Sleep	8:48:17h(SD1:01:02)	9:01:35h(SD1:00:20)	-	0.049

Italics denote a statistical trend (P < 0.1)

4.2.2 Soft Tissue Morphology

As a part of the orthodontic screening exam, two intra-oral soft tissue factors implicated as probable causes of OSA were evaluated. Tonsillar and tongue size relative to the size of the oral cavity were subjectively assessed.

4.2.2.1 Tonsillar Hypertrophy

Hypertrophied tonsils were found to be significantly related to loud snoring. (Table XXV) They were also found to be enlarged in patients who were screened during the winter months (January through April) compared to those screened in other periods over the school year [$P = 0.031$, OR = 2.1(CI = 1.1-4.2)]. A statistically significant protective association was also found between enlarged tonsils and a decrease in tooth clenching.

Table XXV. Statistical Associations Between Evaluated Tonsillar Morphology and Reported Pediatric OSA Symptoms

	Large Tonsils	Normal Tonsils	OR (95% CI)	*P-value*
Usually Snores	*16.7%*	*9.8%*	*1.8(1.0-3.4)*	*0.054*
Snores Loudly	10.1%	4.3%	2.5(1.1-5.5)	0.027
Clenching Teeth	8.7%	17.9%	0.4(0.2-0.9)	0.019

Italics denote a statistical trend ($P < 0.1$)

4.2.2.2 Macroglossia

An enlarged tongue was significantly associated with reported child obesity and also with tooth clenching. (Table XXVI) No other pediatric OSA symptoms were found to be statistically related to evaluated macroglossia.

Table XXVI. Statistical Associations Between Evaluated Macroglossia and Reported Pediatric OSA Symptoms

	Large Tongue	Normal & Small Tongue	OR (95% CI)	*P-value*
Obesity	50.0%	1.8%	52.6(6.8-500)	0.003
Clenching Teeth	75.0%	16.0%	15.9(1.6-143)	0.015

4.2.3 Mouth Breathing

The breathing pattern of the subjects was both assessed in the screening exam and also twice in the patient questionnaires. In all cases, significant associations were found between predominant mouth breathing and a large number of pediatric OSA symptoms. Symptoms of usual snoring, loud snoring, heavy breathing during sleep, trouble breathing during sleep, and dry mouth on awakening were all significantly associated with all three assessments of mouth breathing. A number of other symptoms were significantly related to mouth breathing in one or two of the assessments. (Tables XXVII to XXIX)

The only protective effect detected was that mouth breathing evaluated during the patient exam was related to increased sleeping during the night ($P = 0.047$).

Table XXVII. Statistical Associations Between Evaluated Mouth Breathing and Reported Pediatric OSA Symptoms

	Observed Mouth Breathing	Observed Mixed & Nose Breathing	OR (95% CI)	*P-value*
Usually Snores	18.9%	8.8%	2.4(1.4-4.2)	0.002
Always Snores	*5.6%*	*2.2%*	*2.7(1.0-7.1)*	*0.066*
Snores Loudly	12.6%	3.3%	4.2(2.0-8.9)	<0.001
Heavy Breathing	30.7%	14.3%	2.7(1.7-4.2)	<0.001
Trouble Breathing	10.2%	3.7%	3.0(1.4-6.3)	0.006
Day Mouth Breathing	68.0%	24.9%	6.4(4.2-9.8)	<0.001
Dry Mouth on Awakening	53.1%	31.6%	2.5(1.6-3.6)	<0.001
Unrefreshed in Morning	*26.4%*	*19.2%*	*1.5(1.0-2.4)*	*0.086*
Sleepy Per Teacher	8.6%	1.9%	4.8(1.9-11.8)	0.001
Does Not Listen	*20.9%*	*13.4%*	*1.7(1.0-2.8)*	*0.051*
Easily Distracted	35.7%	24.5%	1.7(1.1-2.6)	0.014
Fidgets	*27.9%*	*19.8%*	*1.6(1.0-2.4)*	*0.053*
Poor Sleep Quality	7.8%	2.8%	2.9(1.3-6.9)	0.017
Fewer Hours of Sleep	9:17:45h(SD0:56:12)	9:05:45h(SD1:00:36)	-	0.047

Italics denote a statistical trend (P < 0.1)

Table XXVIII. Statistical Associations Between Reported Mouth Breathing and Reported Pediatric OSA Symptoms

	Reported Mouth Breathing	Reported Mixed & Nose Breathing	OR (95% CI)	*P-value*
Usually Snores	27.1%	8.9%	3.8(2.1-7.0)	<0.001
Snores Loudly	15.7%	4.0%	4.5(2.1-9.9)	<0.001
Heavy Breathing	39.4%	15.1%	3.7(2.1-6.2)	<0.001
Trouble Breathing	17.1%	3.5%	5.7(2.6-12.3)	<0.001
Day Mouth Breathing	80.3%	28.0%	10.5(5.7-19.4)	<0.001
Dry Mouth on Awakening	57.7%	33.5%	2.7(1.6-4.5)	<0.001
Unrefreshed in Morning	*29.6%*	*19.5%*	*1.7(1.0-3.0)*	*0.060*
Sleepy Per Teacher	8.5%	2.7%	3.3(1.2-8.9)	0.025
Difficult to Awake	*32.4%*	*22.5%*	*1.7(1.0-2.8)*	*0.074*
Does Not Listen	23.9%	13.9%	2.0(1.1-3.6)	0.033
Interrupts	*18.3%*	*10.8%*	*1.9(1.0-3.6)*	*0.075*

Italics denote a statistical trend (P < 0.1)

Table XXIX. Statistical Associations Between Reported Daytime Mouth Breathing and Reported Pediatric OSA Symptoms

	Deported Daytime Mouth Breathing	Reported Daytime Mixed & Nose Breathing	OR (95% CI)	*P-value*
Usually Snores	19.5%	6.6%	3.4(2.0-5.8)	<0.001
Always Snores	5.1%	1.8%	2.9(1.1-7.8)	0.036
Snores Loudly	10.6%	2.6%	4.5(2.1-9.7)	<0.001
Heavy Breathing	32.0%	10.3%	4.1(2.6-6.4)	<0.001
Trouble Breathing	11.1%	2.1%	5.9(2.6-13.6)	<0.001
Observed Apneas	*3.4%*	*1.0%*	*3.5(1.0-12.0)*	*0.051*
Dry Mouth on Awakening	59.4%	24.2%	4.5(3.1-6.5)	<0.001
Unrefreshed in Morning	28.6%	16.4%	2.0(1.4-3.1)	0.001
Somnolence	*10.3%*	*5.8%*	*1.9(1.0-3.4)*	*0.068*
Difficult to Awake	29.9%	20.2%	1.7(1.1-2.5)	0.011
Does Not Listen	21.2%	11.9%	2.0(1.3-3.1)	0.004
Easily Distracted	35.3%	22.2%	1.9(1.3-2.8)	0.001
Fidgets	35.3%	14.4%	3.2(2.2-4.8)	<0.001
Agitated	13.2%	4.8%	3.0(1.6-5.6)	0.001
Interrupts	17.6%	8.8%	2.2(1.3-3.6)	0.002
Obesity	3.9%	1.3%	3.2(1.03-9.9)	0.042
Clenching Teeth	*20.1%*	*14.4%*	*1.5(1.0-2.3)*	*0.081*
Poor Sleep Quality	6.0%	2.5%	2.4(1.04-5.7)	0.041

Italics denote a statistical trend (P < 0.1)

4.2.4 Obesity

Overweight and obesity calculated by sex-specific BMI age-for-growth charts was significantly related to reported obesity. (Table XXX) In another cross tabulation, only the overweight category was compared to the other combined categories. (Table XXXI) Of the patients calculated as being obese, 14.6% of these ($P < 0.001$, OR 15.1, 95% CI = 4.9-47.6) were reported as obese by their parents. Obese patients were also found to be heavy breathers during sleep.

The non-obese and non-overweight were found to have statistically significant protective relationships with feeling unrefreshed in the morning, daytime somnolence and being easily distracted.

Table XXX. Statistical Associations Between Calculated Overweight and Obese BMI Categories and Reported Pediatric OSA Symptoms

	BMI Overweight & Obese	BMI Underweight & Healthy Weight	OR (95% CI)	*P-value*
Unrefreshed in Morning	13.7%	22.8%	0.5(0.3-0.9)	0.027
Somnolence	3.1%	8.8%	0.3(0.1-0.9)	0.036
Easily Distracted	16.8%	29.1%	0.5(0.3-0.8)	0.005
Fidgets	14.5%	23.5%	0.6(0.3-0.9)	0.029
Obesity	8.4%	0.4%	20.8(4.5-90.9)	0.000

Table XXXI. Statistical Associations Between Calculated Obese BMI Category and Reported Pediatric OSA Symptoms

	BMI Obese	BMI Underweight, Healthy Weight & Overweight	OR (95% CI)	*P-value*
Snores Loudly	*10.6%*	*4.8%*	*2.4(0.9-6.5)*	*0.090*
Heavy Breathing	29.2%	16.5%	2.1(1.1-4.0)	0.045
Unrefreshed in Morning	4.2%	22.2%	0.2(0.04-0.6)	0.001
Somnolence	8.2%	0%	0.9(0.90-0.94)	0.040
Easily Distracted	27.8%	10.4%	0.3(0.1-0.8)	0.009
Obesity	14.6%	1.1%	15.1(4.9-47.6)	<0.001

Italics denote a statistical trend (P < 0.1)

4.2.5 Allergies, Colds, and Pulmonary Problems

Statistically significant relationships were revealed between pediatric OSA symptoms and reported allergies and sinus problems, frequent colds, and pulmonary problems. (Tables XXXII to XXXIV) Trouble breathing at night was significantly associated with all three categories. Multiple symptoms from snoring, daytime sleepiness, behavioural and sleep categories were statistically associated with these reported airway problems.

Table XXXII. Statistical Associations Between Reported Allergies and Reported Pediatric OSA Symptoms

	Allergies	No Allergies	OR (95% CI)	*P-value*
Heavy Breathing	23.5%	15.6%	1.7(1.1-2.6)	0.034
Trouble Breathing	9.6%	3.6%	2.8(1.3-6.0)	0.008
Unrefreshed in Morning	27.5%	18.2%	1.7(1.1-2.6)	0.019
Difficult to Awake	30.7%	21.3%	1.6(1.1-2.5)	0.026
Difficulty Organizing	*16.9%*	*10.9%*	*1.7(1.0-2.8)*	*0.062*
Fidgets	29.3%	18.7%	1.8(1.2-2.8)	0.008
Interrupts	16.7%	10.2%	1.8(1.04-3.0)	0.041
Clenching Teeth	*21.2%*	*14.7%*	*1.6(1.0-2.5)*	*0.074*
Poor Sleep Quality	6.7%	2.9%	2.4(1.02-5.6)	0.049
Difficulty Initiating Sleep	23:21min(SD19:59)	19:30min(SD13:50)	-	0.031

Italics denote a statistical trend (P < 0.1)

Table XXXIII. Statistical Associations Between Reported Colds and Reported Pediatric OSA Symptoms

	Frequent Colds	No Frequent Colds	OR (95% CI)	*P-value*
Trouble Breathing	17.6%	4.7%	4.3(1.2-16.0)	0.050
Day Mouth Breathing	70.6%	32.9%	4.9(1.7-14.1)	0.003
Unrefreshed in Morning	*41.2%*	*20.0%*	*2.8(1.0-7.5)*	*0.060*
Somnolence	41.2%	6.3%	10.3(3.7-28.7)	<0.001
Sleepy Per Teacher	23.5%	2.8%	10.9(3.2-37.0)	0.002
Difficult to Awake	58.8%	22.6%	4.9(1.8-13.1)	0.002
Easily Distracted	*47.1%*	*26.2%*	*2.5(1.0-6.6)*	*0.090*
Fidgets	47.1%	20.7%	3.4(1.3-9.0)	0.015
Interrupts	41.2%	10.9%	5.7(2.1-15.5)	0.002
Poor Scholastic Results	*23.1%*	*7.8%*	*3.5(0.9-13.3)*	*0.083*

Italics denote a statistical trend (P < 0.1)

Table XXXIV. Statistical Associations Between Reported Pulmonary Problems and Reported Pediatric OSA Symptoms

	Pulmonary Problems	No Pulmonary Problems	OR (95% CI)	*P-value*
Heavy Breathing	53.8%	16.9%	5.7(1.9-17.4)	0.003
Trouble Breathing	30.8%	4.5%	9.4(2.7-32.7)	0.003
Interrupts	*30.8%*	*11.4%*	*3.4(1.0-11.6)*	*0.056*

Italics denote a statistical trend (P < 0.1)

4.2.6 Treatments and Medications

Treatments of airway problems were reported in the medical health questionnaire. Patients who had undergone surgical ablation of the tonsils or adenoids had increased reports of apneas ($P < 0001$). Those who did not report having the procedure reported more delayed growth since birth ($P = 0.008$). (Table XXXV) Of those patients reporting bronchodilator medication use, a statistically significant relationship was found with heavy breathing and trouble breathing at night. (Table XXXVI)

The medication having the largest reported use was psychostimulants. The medications used in ADHD had a significant relationship with some behavioural symptoms. (Table XXXVII) Difficulties organizing tasks, easy distraction by other stimuli, and fidgeting were all significantly associated with this medication use.

Table XXXV. Statistical Associations Between Reported Adenotonsillectomy Procedure and Reported Pediatric OSA Symptoms

	No Adenotonsillectomy	Adenotonsillectomy	OR (95% CI)	*P-value*
Observed Apneas	1.0%	7.8%	0.1(0.03-0.4)	0.001
Delayed Growth	18.2%	6.5%	3.2(1.3-8.2)	0.008

Table XXXVI. Statistical Associations Between Reported Bronchodilator Medication Use and Reported Pediatric OSA Symptoms

	Bronchodilator Use	No Bronchodilator Use	OR (95% CI)	*P-value*
Heavy Breathing	55.6%	17.1%	6.1(1.6-23.3)	0.011
Trouble Breathing	33.3%	4.5%	10.6(2.5-45.5)	0.007

Table XXXVII. Statistical Associations Between Reported Psychostimulant Medication Use and Reported Pediatric OSA Symptoms

	Psychostimulant Use	No Psychostimulant Use	OR (95% CI)	*P-value*
Does Not Listen	*24.3%*	*14.3%*	*1.9(0.9-4.3)*	*0.099*
Difficulty Organizing	35.1%	10.9%	4.4(2.1-9.2)	<0.001
Easily Distracted	70.3%	23.8%	7.6(3.6-15.6)	<0.001
Fidgets	*35.1%*	*20.5%*	*2.1(1.0-4.3)*	*0.060*
Agitated	18.9%	6.8%	3.2(1.3-7.8)	0.016
Bruxism	*21.6%*	*11.3%*	*2.2(1.0-5.0)*	*0.068*

Italics denote a statistical trend (P < 0.1)

4.2.7 Headaches, Bruxism, and Thumb/Finger Sucking Habits

Reports of frequent headaches were significantly related with symptoms of sleepiness, being tired and being difficult to awaken in the morning, easy distraction, poor sleep quality, and morning headaches. (Table XXXVIII)

The parafunctional habit of tooth grinding was also associated with OSA symptoms. (Table XXXIX) Most of these associations were not statistically significant. However, bruxism was significantly associated with another parafunction, tooth clenching. Protective statistically significant relationships were found with delayed growth and less sleep. Bruxers were found significantly to sleep more and to have a more normal growth pattern.

Histories of thumb or finger sucking habits were statistically associated with heavy breathing at night and waking unrefreshed in the morning. (Table XL) These subjects were statistically more often obese than those who did not have a history of a sucking habit.

Table XXXVIII. Statistical Associations Between Reported Frequent Headaches and Reported Pediatric OSA Symptoms

	Frequent Headaches	No Frequent Headaches	OR (95% CI)	*P-value*
Unrefreshed in Morning	56.5%	19.2%	5.4(2.3-12.8)	<0.001
Somnolence	27.3%	6.6%	5.3(2.0-14.4)	0.003
Difficult to Awake	43.5%	22.8%	2.6(1.1-6.1)	0.041
Easily Distracted	47.8%	25.9%	2.6(1.1-6.1)	0.029
Agitated	*17.4%*	*7.3%*	*2.7(0.9-8.2)*	*0.091*
Morning Headache	43.5%	1.9%	39.7(14-109)	<0.001
Poor Sleep Quality	17.4%	3.3%	6.1(1.9-20.0)	0.009

Italics denote a statistical trend (P < 0.1)

Table XXXIX. Statistical Associations Between Reported Bruxism and Reported Pediatric OSA Symptoms

	Bruxism	No Bruxism	OR (95% CI)	*P-value*
Dry Mouth on Awakening	*45.8%*	*34.7%*	*1.6(1.0-2.6)*	*0.068*
Difficult to Awake	*33.3%*	*22.4%*	*1.7(1.0-2.9)*	*0.054*
Does Not Listen	*22.2%*	*14.1%*	*1.7(1.0-3.2)*	*0.079*
Difficulty Organizing	*19.7%*	*11.6%*	*1.9(1.0-3.6)*	*0.058*
Delayed Growth	5.6%	18.1%	0.3(0.1-0.7)	0.006
Clenching Teeth	51.4%	11.4%	8.2(4.8-14.1)	<0.001
Fewer Hours of Sleep	9:25:48h(SD0:54:25)	9:06:10h(SD1:00:07)	-	0.010

Italics denote a statistical trend (P < 0.1)

Table XL. Statistical Associations Between Reported History of Finger/Thumb Sucking Habit and Reported Pediatric OSA Symptoms

	History of Finger Sucking Habit	No History of Finger Sucking Habit	OR (95% CI)	*P-value*
Heavy Breathing	27.0%	15.8%	2.0(1.2-3.3)	0.010
Unrefreshed in Morning	28.4%	19.0%	1.7(1.04-2.7)	0.043
Difficult to Awake	*30.4%*	*22.0%*	*1.5(1.0-2.5)*	*0.073*
Morning Headache	*6.9%*	*2.8%*	*2.5(1.0-6.4)*	*0.069*
Obesity	4.9%	1.2%	4.2(1.3-14.0)	0.026

Italics denote a statistical trend ($P < 0.1$)

4.2.8 Sleep Quantity and Quality

An assessment of patient age relative to their reported hours of sleep per night was performed. A statistically significant decrease in the hours of reported sleep (from ≈ 10.5h to 8h) was found as subjects increased in age. (Figure 4) This significance was found using an analysis of variance (ANOVA). Although the Spearman correlation coefficient was statistically significant ($P < 0.001$, $R^2 = 0.356$), the R^2 revealed a moderate correlation (≈ 35%) to explain the variability.

The total hours of sleep were also compared to symptoms of pediatric OSA. (Table XLI) The symptoms of being difficult to awaken, feeling unrefreshed in the morning, and being sleepy during the day were all statistically related to having between 15 and 30 minutes of less sleep than subjects not reporting these symptoms.

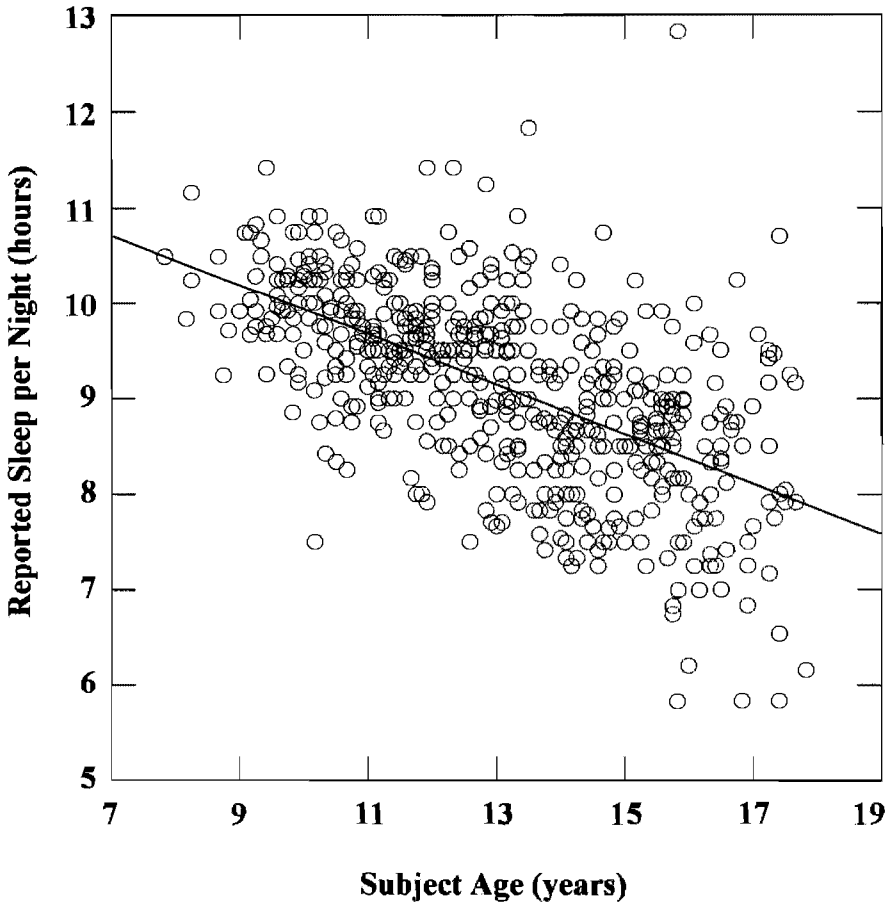

Figure 4. Average hours of reported subject sleep per night

Table XLI. Statistically Significant Associations Between Reported Sleep Quantity and Selected Reported Pediatric OSA Symptoms

	Difficult to Awake	**Not Difficult to Awake**	***P-value***
Fewer Hours of Sleep	8:45:06h(SD1:03:04)	9:03:55h(SD0:59:10)	0.001
	Unrefreshed in Morning	**Not Unrefreshed in Morning**	***P-value***
Fewer Hours of Sleep	8:36:11h(SD1:05:15)	9:05:25h(SD0:57:57)	<0.001
	Somnolence	**No Somnolence**	***P-value***
Fewer Hours of Sleep	8:33:25h(SD1:11:14)	9:01:35h(SD0:59:21)	0.014

DISCUSSION

5. DISCUSSION

In contrast to OSA in adults which is predominantly associated with obesity, pediatric OSA is primarily associated with adenotonsillar hypertrophy and with morphological features that are related to the long-face patient: dolichofacial, high MPA, narrow palate, severe crowding of the maxilla and mandible, allergies, frequent colds, and habitual mouth breathing.

5.1 Epidemiology

Increased attention has been placed on pediatric OSA over the last few years. The serious consequences of this disorder, such as behaviour and cognitive impairments and cardiovascular consequences, have focused on the importance of its early detection and treatment (Ameli 2007). The prevalence of snoring and OSA has predominantly been assessed in clinic-based settings of children suspected to have SDB. The orthodontic clinic provides a setting where, other than having malocclusions, mostly healthy children and adolescents can be assessed for SDB. The orthodontist is uniquely qualified to evaluate and monitor abnormal facial growth (Rubin 1979). Very few studies have used the orthodontic setting to study the general prevalence of snoring and sleep disturbance and related morphological traits in children and adolescents (Nelson 2001, Hultcrantz 1995).

The study population between 7 and 17 years of age (mean = 13.01 years), mirrors that which is found in the general orthodontic patient population (Proffit 2007). A slight predominance of female patients (55.5%) is also similar to what is found elsewhere in the orthodontic literature.

Using BMI percentiles, the levels of childhood obesity in the sample population were found to be slightly higher (8.2%) than a recent Canadian study which found levels of 6% (Boyce 2008). However, the overall prevalence of overweight and obese (22.4%) mirrored the results of that study. Reported obesity by parents in the questionnaire was lower at 2.2%. These high levels of childhood and adolescent overweight and obesity follow trends of increased prevalence over the last 25 years. This overweight and obese population is at higher risk of pediatric OSA (Redline 1999).

Using the subjective scales of the orthodontic evaluation, the prevalence of facial morphological traits was considered to be in the normal range for most patients. The average patient was found to have a mesofacial face, with a convex, Class I profile.

Measured dental malocclusion characteristics were found to more closely reflect those found in the NHANES III survey than from a previously published study on Quebec schoolchildren, which had an unusually high percentage of Class III subjects (Proffit 1998, Payette 1989). The NHANES III survey results of the general population in the United States demonstrate that the vast majority of patients have a Class I normal occlusion (30%) or malocclusion (50-55%) (Proffit 1998). It is therefore expected that a larger percentage of patients with malocclusions would present for treatment at an orthodontic clinic, as most Class I normal occlusions would not seek treatment. This increase was found in the prevalence data from our study population. The prevalence of the malocclusion characteristics in this population was similar to those published in previous studies (Bishara 2001). Severe overjet and posterior crossbites were also found to be higher than in the general population. The one malocclusion characteristic that was found to be lower than expected, based on previous studies, was that of open bites.

Hypertrophic tonsils and macroglossia were assessed as soft tissue causes of upper airway obstruction. Prevalence of enlarged tonsils changes with age during childhood and is difficult to isolate. The prevalence of hypertrophic tonsils in our children and adolescents was found to be 17.3%. This is a slightly higher than what has been reported for schoolchildren in the literature (Kara 2002). A large percentage of our patients also

reported having tonsillectomy or adenoidectomy. Few pediatric subjects had an enlarged tongue. In non-syndromic patients, a low prevalence of macroglossia is expected (Ugar-Cankal 2005).

Allergies and asthma were frequent in our pediatric population. One quarter was affected by all types of allergies and 9.3% reported being asthmatic. Prevalence of asthma from the NHANES III survey was estimated at 6.7% in children from 2 months to 16 years of age (Rodríguez 2002). Though the literature has described that 90% of patients with asthma have allergic rhinitis, only 2.8% of our sample patients reported having frequent sinusitis or colds (Lampasso 2004). A remarkably low (1.5%) percentage of patients reported use of bronchodilators when compared to reported asthma. This may be due to the open ended question related to medication use.

Reports of frequent headaches affected 3.8% of the patient population. This is significantly lower than estimates of frequent headaches occurring in children and adolescents. These have been reported to be between 6.7% and 11.5% (US Department of Health and Human Services 2006, Abu-Arefeh 1994).

The prevalence of parafunctional habits of clenching and grinding as well as TMD symptoms was similar to what has been reported in the literature (Magnusson 2005, 1993, Thilander 2002, Laberge 2000, Widmalm 1995). In the present study, few patients had reported TMD sounds or difficulties opening or closing the mandible due to locking.

Breathing patterns were assessed both during the exam and twice within the questionnaire instrument. None of the assessments provided the same prevalence. This is not unusual as determining the primary mode of respiration is difficult without the use of rhinometry. Humans, though primarily nasal breathers, often have a mixed type of breathing (Proffit 2007). In our patient population, mixed mouth and nose breathing and nose breathing alone predominated in both reported and assessed respiration patterns. This is consistent with the literature which reports that total nasal obstruction, leading to mouth breathing only, is relatively rare (Proffit 2007). However, mouth breathing can be

a predominant respiratory pattern in patients who have significant nasal obstruction. Having a dry mouth on awakening is also a sign of nighttime mouth breathing.

One published study of children and adolescents of 6 to 17 years of age from an orthodontic setting, has assessed SDB prevalence (Nelson 2001). The prevalence of SDB signs and symptoms in our study was similar to their results. Habitual snoring was demonstrated to be 10.9%. Those reported always to snore was 2.9%. A small percentage (1.8%) reported observed apneas. These data are in the ranges of previously published studies (Gislason 1995, Ali 1993, Redline 1999). A recent meta-analysis demonstrated that reported sleep disordered breathing was found in 4% to 11% of the pediatric population. Pediatric snoring was 7.45%, with ranges of reports of always snoring between 1.5% and 6%. Reported apneic events during sleep were found to be between 0.2% and 4% (Lumeng 2008). As parents do not often share rooms with their children, they are not as likely to be present to observe cessation of breathing. This has been a reported reason to suspect under-diagnosis of apneas and SDB in the pediatric population (Lumeng 2008).

Daytime sleepiness demonstrated similar prevalence rates as demonstrated in other studies (Nelson 2001). Subjects reported similar rates of being difficult to awaken and having unrefreshed sleep. Fewer subjects reported excessive daytime sleepiness. Though daytime somnolence is a major hallmark in adult OSA, children tend to demonstrate less daytime sleepiness in relation to pediatric OSA (Amin 2006).

Total sleeping time decreases as children age (Jenni 2005). Between the ages of 7 and 17, there was an expected decrease in the hours of sleep per night. The average time spent falling asleep was approximately 20 minutes. Large variations were seen for both total hours of sleep per night and total time before falling asleep. The age of the patient is related to these variations. These differences may also be affected by the time of the year in which the questioning occurred, or whether, as was stated in the instructions, the parent actually reported values for the majority of nights over the previous month. In questioning sleep habits, it is important to discern between holidays, weekends and

school nights. Reported sleep patterns can vary wildly between these times (Wolfson 2003).

Neurobehavioural factors are associated with pediatric OSA. The estimated prevalence of ADHD in the United States is estimated at 3% to 7% in children and adolescents (American Psychiatric Association 2000). Symptoms related ADHD behaviour in our study ranged in prevalence from 7.7% to 26.7%. Far from diagnosing ADHD from 7 questions in a survey, these percentages demonstrate a significant behavioural problem in the cohort. The use of psychostimulants, the category of medication used in the treatment of ADHD, was self-reported at 6.1%. No categorization was used for the question about taking medications regularly. Parents wrote down the name of the medication for this question. A more structured set of answers might elucidate a higher percentage of patients taking these medications.

5.2 Orthodontic Evaluation and Pediatric OSA Symptom Associations

The clinical picture provided by the statistically significant associations in this study is that SDB is typical in a long-face syndrome patient. The mouth breathing, narrow palate, high MPA, dolichofacial patient with severe maxillary and mandibular crowding demonstrated the most significant relationships with pediatric OSA symptoms. Reported allergies and frequent colds and sinusitis were also implicated.

Controversy exists in the orthodontic literature regarding the cause and effect relationships between nasal obstruction, mouth breathing, and facial growth (Vig 1998). The terms respiratory obstruction syndrome, adenoidal facies, long-face syndrome and vertical maxillary excess have all been used to describe the morphologic traits associated with chronic nasal obstruction (Graber 2005). Features that have been associated with predominant mouth breathing include: increased facial height, obtuse gonial and MPA, retrognathism, open mouth posture, narrowed nose, short upper lip, increased incisor OJ, open bite, Angle Class II malocclusion, dental crowding, narrow

V-shaped palate, posterior dental crossbite, and enlarged adenoids and tonsils (Bresolin 1983, Freng 1979, Woodside 1979, Linder-Aronson 1979, 1970). In previous studies on changes in craniofacial morphology after experimental obstruction of the nasopharyngeal airway in rhesus monkeys, Harvold and colleagues (1981) implicated mouth breathing in the growth behaviour of craniofacial structures. Other human studies have demonstrated a normalization of facial growth after adenotonsillectomy (Zettergren-Wijk 2006, Linder-Aronson 1993). Other viewpoints refute the cause and effect relationship by demonstrating that mouth breathing after increased nasal resistance does not always show altered craniofacial growth (Vig 1998).

This cross-sectional study does not purport to demonstrate a cause and effect relationship between pediatric OSA and features of the long-face patient. An attempt was made only to associate morphological features of orthodontic patients to symptoms of OSA. After statistical analysis, the morphological features of our cohort demonstrating a positive relationship with OSA were found to be remarkably similar to the typical long-face patient. This is not surprising as this facial presentation has morphological features which are related to anatomical obstruction of the upper airway.

Obstruction can occur anywhere along the upper airway. There are many anatomical locations for obstruction in OSA. Though adenoid and tonsillar hypertrophy have been implicated as the primary cause of pediatric OSA, other features contribute to this airway resistance. It is important to view the clinical picture as a whole, and not only concentrate on one anatomical structure.

In the present study, factors from the Pediatric Sleep Questionnaire which demonstrated the most positive associations with morphological factors were from the snoring problems, breathing problems, and daytime sleepiness symptom categories. Snoring loudly, usually snoring, dry mouth on awakening, mouth breathing, and heavy breathing were the questions reporting the most significance with morphological and health-related traits. These OSA symptoms were among those that, according to Chervin *et al.* (2000), were found to have the highest predictive value of SDB. Reported poor sleep

quality from the Pittsburgh Sleep Quality Index questionnaire was also related to several clinical features.

In our survey, large tonsils were found to be related only to loud snoring as an OSA symptom. Tonsils and adenoids are commonly reported as the primary cause of pediatric OSA; therefore more statistically significant relationships were expected. The scale which was used in our study graded the tonsils as normal or large. Using a 5-point scale to measure tonsil size may have yielded more accurate results by placing more focus on their evaluation in relation to a scale. Reports of adenotonsillectomy only demonstrated significance with more normal growth. A protective relationship was found with those who reported observed apneas. Those children with reported apneas were found to have already had an adenotonsillectomy. This is not likely the case as tonsillectomy has been reported to be curative of OSA in at least 80% of cases (Suen 1995). It is more likely that the question should have been phrased differently to report cessation of breathing over a specific period of time. Parents likely linked a previous diagnosis of pediatric OSA and the adenotonsillectomy surgery that was undertaken to cure it.

The morphological factors evaluating the sagittal dimension were only weakly associated with a few factors of SDB. Poor scholastic results, morning headaches and bruxism were statistically significant features of mandibular retrusion. The reason for this poor statistical relationship may be due to neuromuscular adaptation of the tongue in regards to the retrusive mandible impingement on the airway space. It is also possible that only severe micrognathia, as observed in certain syndromes, may be related to symptoms of pediatric OSA. An unexpected association was found between having mandibular retrusion and increased sleep. Class II patients also tended to fall asleep faster. Both relationships were found to be statistically significant.

Obesity was another factor where expected relationships were not detected. This study evaluated a general pediatric population and not an OSA population. Obesity in adults has been reported as the primary cause of OSA. In addition, it is thought to be related to pediatric OSA. One area of concern in this study was the underreporting of obesity by

parents compared to calculated obesity using BMI. However, both calculated and reported obesity were compared to OSA symptoms and did not reveal any statistical significance, except with each other. Unexpected protective associations were found between obesity and daytime tiredness, sleepiness, and easy distraction. Fat deposits in children may be distributed differently when compared to adult patients. These results seem to agree with the observation that the majority of children with OSA are of normal weight (Carroll 1995).

Medication use was significantly associated with certain signs and symptoms of SDB. Bronchodilators used in asthmatic patients were related to breathing problems. Reported use of psychostimulants was related to symptoms of inattention and hyperactivity. Increased associations might have been possible had the medication question been posed with categorical answers. It is important to note that though the type of medication was self-reported it still yielded significant results.

An increased frequency of headaches was significantly related with poor sleep quality, problems of daytime sleepiness, and distraction during the day. Nocturnal and morning headaches negatively affect sleep. Reported frequent headaches demonstrated an expected relationship with sleep parameters.

An open bite, enlarged tongue, bruxism, and a positive history of thumb sucking were poor predictors of pediatric OSA symptoms. This study did not detect a strong association between OSA symptoms and open bites, possibly because few patients were observed to have this malocclusion. An enlarged tongue was significantly associated with obesity and tooth clenching. Thumb sucking was also significantly associated with obesity as well as with reported heavy breathing and feeling unrefreshed after sleep. Though it is commonly known as a parafunctional disorder of sleep, reported bruxism did not reach a level of significance in associations with pediatric OSA symptoms (Lavigne 1999).

Hours of sleep and time to fall asleep were correlated to certain factors. A linear relationship between increased subject age and decreased hours of sleep was found from 7 to 17 years. This relationship was expected as total sleeping time decreases during childhood and adolescence (Jenni 2005). A statistically significant decrease in total sleep time was also found in those reporting symptoms of daytime sleepiness. This relationship between a lack of sleep and increased daytime symptoms of fatigue was as expected.

Despite being an ideal setting for screening morphological features associated with pediatric OSA, few published studies have screened a large orthodontic population and attempted to correlate OSA symptoms with craniofacial characteristics. An aforementioned study by Nelson and Kulnis (2001) used an orthodontic population as a patient pool to study prevalence and associations within pediatric OSA factors only. No attempt was made to correlate OSA symptoms and morphological patient features. A SDB study on 4 year-olds, with a 2 year follow-up, evaluated a subset of 100 snoring patients in the cohort for malocclusions (Hultcrantz 1995, Löfstrand-Tideström 2007). Another study by Ameli (2007) orthodontically evaluated a cohort of suspected pediatric OSA patients prior to adenotonsillectomy. A large population-based cross-sectional study evaluating multiple pediatric OSA morphological features is needed to identify those that are associated with OSA.

No morphological or health-related feature demonstrated statistical association with every pediatric OSA symptom. The only way to evaluate a feature's statistical relationship with OSA itself would have been to have every child undergo overnight PSG testing. This was beyond the scope of this study.

Relationships between morphological features, positive health-related questions, and pediatric OSA symptoms were identified in order to determine areas of future research. The identification of these areas of statistical associations could also aid the informed orthodontist in screening potential patients with pediatric OSA.

5.3 Study Limitations and Future Improvements

Several limitations of this pilot study exist:

- Owing to the nature of the evaluation, the screening exam remains relatively subjective. Certain features can be measured rapidly, but most are subjectively evaluated. Facial and dental proportions and angles can be measured on cephalometric radiographs and dental casts, but these are not routinely taken in a screening examination. Digital photographs could be added to the screening exam to quantitatively evaluate facial proportions and profile. As dental charts and patient records become computerized, the availability of more objective information will allow for precise analysis in future studies.

- The patients were not examined using the gold standard diagnostic technique of polysomnography. Due to a lack of universal availability and excessive financial and manpower cost, polysomnography cannot be carried out routinely on all patients. Ambulatory monitoring may help to remedy this situation in the future. Though not a supervised exam in a controlled setting, it allows for portability and decreased cost.

- This study relied upon parents or guardians reporting on their children. Though parent questionnaires have been validated as tools in identifying pediatric OSA, others have demonstrated parental over reporting of some symptoms (Chervin 2000, Carroll 1995). Due to the nature of this pilot study, these questionnaires demanded that the parents respond to 141 questions. The excessive volume of questions may contribute to possible errors in parental answering. Certain questions with a social stigma attached to them may also have been under reported. Academic achievement and obesity are two such questions. As previously stated, there was a large discrepancy between calculated obesity and parents reporting that their child is obese. Even though the BMI was reported as age and sex matched, there may be

errors in the measurement tool. On the other hand, parents may also be in denial. Parents may consider their children as reflections of themselves, and may be less likely to identify problems of a social nature. This puts into question parental reporting of certain factors. In addition, certain questions may lose accuracy in a "yes" or "no" type answer. Further information could be gained by having a scale of possible answers (e.g. frequency of headaches).

- Omissions in the screening exam included a measure of maxillary sagittal position and a "no crowding" category in the dental arch exam. A measure of the nasolabial angle could have given an indication of the relative position of the maxilla. These measures should be included in future orthodontic screening evaluation forms.

- As previously mentioned, a small number of statistical associations demonstrated unexpected protective effects between morphological and health-related features and pediatric OSA symptoms. Nocturnal enuresis was found in an unexpected relationship demonstrating a protective effect with a decreased facial width and a retrusive mandible. Mandibular deficient patients were also found to fall asleep earlier and sleep for longer periods of time. Unexplained, protective effects were also found between reported tooth clenching and dental crowding. A protective relationship was found between overweight and obese patients and daytime sleepiness and distraction. Tooth grinding was also found to occur in patients who slept more and who did not report delayed growth. In any study with such a large number of statistical tests and where significance is set at $P < 0.05$, some associations will be due to chance alone. Other relationships may warrant further investigation with PSG. Despite these unanticipated associations, the vast majority of statistically significant relationships in this study were found between expected aggravating effects.

- Generalizing these results to a wider pediatric population is not possible, because the population sample is one seeking orthodontic care for esthetic and functional

reasons. Though in a university clinic setting with lower associated treatment cost, not all socioeconomic groups will be represented in the sample. The university is also located in an urban area, making accessibility an issue for the rural population. The population in this study is a general orthodontic population.

CONCLUSIONS

6. CONCLUSIONS

According to the American Academy of Pediatrics (2002) clinical practice guidelines for SDB, children should be routinely screened for snoring. Those that are symptomatic should undergo PSG for diagnosis. SDB is a continuum extending from primary snoring to OSA. Though SDB is a common childhood condition which is most frequently associated with adenotonsillar hypertrophy, craniofacial malformations, oropharyngeal dysfunction, and neuromuscular conditions also contribute to the disorder. SDB has significant effects on child behaviour, performance, and health. As a specialist who examines morphological characteristics, an orthodontist is highly qualified to screen for possible SDB in children and adolescents.

This study has shown the prevalence and associations of evaluated morphological traits, and reported health-related features and pediatric OSA symptoms in a child and adolescent population seeking orthodontic care. The prevalence of these features generally mirrored those that have been previously published in the literature.

This study demonstrated statistically significant associations between clinical signs of malocclusion and reported symptoms of SDB. Clinical factors demonstrating deficiencies in the maxillo-mandibular transverse dimension, as well as increased vertical facial height were significantly related to reported symptoms of SDB. However, no such relationship was found for reduced antero-posterior dimensions. Overall, the statistical associations between the morphological and health features and the pediatric OSA symptoms painted a diagnostic portrait of our pediatric SDB patient. This at-risk pediatric patient is the long-face syndrome patient.

Morphological features from this study that should be retained as risk factors for SDB from the screening exam are the dolichofacial, high MPA, narrow palate, predominantly mouth breathing patient, who also has severe crowding of the maxilla and mandible.

Tonsillar hypertrophy may be best evaluated using a graded approach. The reported health problems to consider are the presence of allergies and asthma, frequent colds and sinusitis, and frequent headaches.

The questions from the sleep questionnaires most likely to be implicated in OSA were related to snoring frequency and quality, trouble breathing at night, mouth breathing, dry mouth on awakening and a scale of assessment of sleep quality.

The limitations of this pilot study prevent the generalization of these results to a larger population. This information should, however, help in reorienting health questionnaires and orthodontic exams towards screening for a significant childhood problem. In future studies, it is hoped that additional diagnostic information made available through digital files, as well as home PSG, may allow for subsets of population seeking orthodontic treatment to be more accurately evaluated.

Current studies in our Orthodontics Section are using PSG to evaluate the effects of surgically assisted rapid palatal expansion on physiological sleep quality and three-dimensional airway volume. The recent results demonstrating improved sleep architecture in normal subjects are promising. As there is a shortage of studies on orthodontic treatment of pediatric OSA, future studies will attempt to identify at-risk cohorts and assess interventions in these patients.

When evaluating their patients, every orthodontist should also be looking beyond the dentition. Orthodontists are in a privileged position to be able to recognize problems of sleep-disordered breathing and direct patients towards diagnosis and treatment. Prevention and treatment of sleep-disordered breathing diminishes the risk of serious health consequences and has the potential to improve a patient's quality of life.

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APPENDIX

8. APPENDIX

8.1 Appendix I: Patient Questionnaires (Medical, Dental, Habits, and Sleep)

QUESTIONNAIRE MÉDICAL ET DENTAIRE

Notez que le genre masculin est utilisé uniquement pour alléger le texte et inclut le féminin.

Nom : _____ Prénom : _____ Sexe : F ☐ - M ☐

Date de naissance : jour ____ mois ____ année ____ Âge : ____

Histoire médicale :	**Oui**	**Non**
Actuellement sous les soins d'un médecin?	☐	☐
Si oui, la raison :		
Prend des médicaments régulièrement?	☐	☐
Si oui, lesquels?		
Problème de saignement prolongé?	☐	☐
Anémie?	☐	☐
Haute/basse pression?	☐	☐
Rhumes fréquents ou sinusites?	☐	☐
Problèmes pulmonaires?	☐	☐
Troubles digestifs?	☐	☐
Diabète?	☐	☐
Troubles thyroïdiens?	☐	☐
Arthrite?	☐	☐
Épilepsie?	☐	☐
Troubles nerveux?	☐	☐
Maux de tête fréquents?	☐	☐
Perte de conscience?	☐	☐
Maux ou limitation de mouvement au cou ou aux épaules?	☐	☐
Maux d'oreilles?	☐	☐
Chirurgie pour enlever les amygdales ou adénoïdes?	☐	☐
Déjà eu radiothérapie (tumeur)?	☐	☐
Allergies?	☐	☐
Fièvre des foins	☐	☐
Asthme	☐	☐
Poussière	☐	☐
Animaux	☐	☐
Autres	☐	☐

Histoire dentaire : Date du dernier examen dentaire : ____ mois ____ année			
Le patient a déjà eu :		**Oui**	**Non**
Traitements dentaires (gencives, traitement de canal, obturations)?		☐	☐
Traitements orthodontiques?		☐	☐
Extractions?		☐	☐
Respire surtout :	Par la bouche?	☐	☐
	Par le nez?	☐	☐
	Moitié par la bouche, moitié par le nez?	☐	☐
Traumatisme :	Sur les dents?	☐	☐
	À la tête ou au cou?	☐	☐
Si oui, quel genre :			
Douleur :	Aux gencives?	☐	☐
	Aux dents?	☐	☐
Déjà sucé son pouce/ses doigts?		☐	☐
Suce encore son pouce/ses doigts?		☐	☐
Troubles de la langue?		☐	☐
Troubles de la parole?		☐	☐
À déjà vu un orthophoniste?		☐	☐
Le patient joue un instrument de musique? Si oui, lequel?		☐	☐

Habitudes :	Oui	Non
1. Est-ce que l'articulation de la mâchoire du patient craque (fait des bruits secs) en ouvrant ou en fermant ou en mastiquant?	☐	☐
2. Est-ce que l'articulation de la mâchoire du patient fait un bruit de grattement (frottement) en ouvrant ou en fermant ou en mastiquant?	☐	☐
3. Est-ce que la mâchoire du patient se bloque de sorte que l'ouverture normale n'est pas possible?	☐	☐
Si oui, est-ce que c'est possible de la débloquer toute seul?	☐	☐
Si non, combien de temps le blocage dure généralement?		
4. Est-ce que la mâchoire du patient bloque de sorte que la fermeture normale n'est pas possible?	☐	☐

5. Est-ce que le patient mastique ou suce :	Jamais ou presque	Parfois	Souvent	Toujours ou presque
Ses lèvres, sa langue ou ses joues?	☐	☐	☐	☐
Ses ongles?	☐	☐	☐	☐
De la gomme à mâcher?	☐	☐	☐	☐
Un crayon ou un stylo?	☐	☐	☐	☐

6. Est-ce que le patient serre les dents?	Oui	Non
	☐	☐

	Jamais ou presque	Parfois	Souvent	Toujours ou presque
Si oui,	☐	☐	☐	☐
Pendant la journée?	☐	☐	☐	☐
Pendant la nuit?	☐	☐	☐	☐

7. Est-ce que le patient grince des dents?	Oui	Non
	☐	☐

	Jamais ou presque	Parfois	Souvent	Toujours ou presque
Si oui,	☐	☐	☐	☐
Pendant la journée?	☐	☐	☐	☐
Pendant la nuit?	☐	☐	☐	☐
Est-ce que cela le dérange?	☐	☐	☐	☐
Si oui, pourquoi?				

	Oui	Non
8. Est-ce que ses dents sont usées?	☐	☐
9. Est-ce que le patient a déjà brisé des plombages ou couronnes?	☐	☐
10. Est-ce que la façon dont les dents ferment est inconfortable?	☐	☐

	Sur le ventre	Sur le dos	Sur le côté	Variable ou ne sais pas
11. En général, quelle est sa posture lors du sommeil?	☐	☐	☐	☐

	Jamais ou presque	Parfois	Souvent	Toujours ou presque
12. Est-ce que sa mâchoire est endolorie ou raide en se réveillant le matin?	☐	☐	☐	☐

13. Est-ce que le patient ressent de la fatigue au niveau des muscles du visage ou de la mastication?	Oui	Non
	☐	☐

	Jamais ou presque	Parfois	Souvent	Toujours ou presque
Lors de son réveil le matin?	☐	☐	☐	☐
Pendant la journée?	☐	☐	☐	☐
Pendant la nuit?	☐	☐	☐	☐

	Augmente	Diminue	Stable	Variable
Comment cette fatigue varie-t-elle?	☐	☐	☐	☐

14. Au cours du **dernier mois**, indiquez jusqu'à quel point son problème de mâchoire rend difficile :	**Pas du tout**	**Un peu**	**Modérément**	**Beaucoup**	**Extrêmement**
Mastiquer	☐	☐	☐	☐	☐
Boire	☐	☐	☐	☐	☐
Exercices physiques	☐	☐	☐	☐	☐
Manger des aliments durs	☐	☐	☐	☐	☐
Manger des aliments mous	☐	☐	☐	☐	☐
La digestion	☐	☐	☐	☐	☐
Nettoyer les dents	☐	☐	☐	☐	☐
Bâiller	☐	☐	☐	☐	☐
Avaler	☐	☐	☐	☐	☐
Parler	☐	☐	☐	☐	☐

Sommeil :	**Oui**	**Non**
1. Durant son sommeil, est-ce que le patient :		
Ronfle plus de la moitié du temps?	☐	☐
Ronfle toujours?	☐	☐
Ronfle bruyamment?	☐	☐
Respire fort ou bruyamment?	☐	☐
A des problèmes ou de la difficulté à respirer?	☐	☐
2. Avez-vous déjà vu le patient :		
Arrêter de respirer durant la nuit?	☐	☐
3. Est-ce que le patient :		
A tendance à respirer par la bouche durant le jour?	☐	☐
Se réveille avec la bouche sèche?	☐	☐
Mouille son lit occasionnellement?	☐	☐
4. Est-ce que le patient :		
Se réveille avec un sentiment de ne pas être reposé?	☐	☐
A un problème de somnolence durant le jour?	☐	☐
Est-ce qu'un professeur ou une autre personne vous a rapporté que le patient somnole durant le jour?	☐	☐
Est difficile à réveiller le matin?	☐	☐
Se réveille le matin avec des maux de tête?	☐	☐
Grandit de façon normale depuis sa naissance?	☐	☐
Est obèse?	☐	☐
5. Souvent, le patient :		
Ne semble pas écouter lorsqu'on lui parle directement.	☐	☐
A de la difficulté à organiser des tâches et des activités.	☐	☐
Est facilement distrait par des stimulis externes.	☐	☐
Gigote ses mains ou ses pieds ou se tortille lorsqu'il est assis.	☐	☐
Ne reste pas en place ou est agité.	☐	☐
Interrompt ou est intrusif avec les autres (exemple : se mêle d'une conversation ou d'un jeux sans y être invité)	☐	☐
6. À l'école, le patient :		
Réussit bien?	☐	☐

Qualité du sommeil :

Instructions : Les questions qui suivent font références aux habitudes de sommeil **du patient** au cours du **dernier mois seulement**. Vos réponses devraient correspondre aux meilleures estimations possibles **pour la majorité** des jours et des nuits du dernier mois. SVP veuillez répondre à toutes les questions.

1.	Durant le dernier mois, à quelle heure vous êtes-vous couché? _____				
2.	Durant le dernier mois, combien de minutes avez-vous pris pour vous endormir à chaque soir? _____ min				
3.	Durant le dernier mois, à quelle heure vous êtes-vous levé le matin? _____				
4.	Durant le dernier mois, combien d'heures de sommeil avez-vous eu par nuit? (ceci peut-être différent du nombre d'heures passées au lit) _____ heures				
5.	**Durant le dernier mois, combien de fois avez-vous eu de la difficulté à dormir parce que vous :**	**Pas durant le dernier mois**	**Moins 1 fois par semaine**	**1 ou 2 fois par semaine**	**3 fois ou plus par semaine**
5.a	Ne pouviez pas vous endormir à l'intérieur de 30 min?	☐	☐	☐	☐
5.b	Vous réveilliez au milieu de la nuit ou tôt le matin?	☐	☐	☐	☐
5.c	Deviez vous lever pour aller à la salle de bain?	☐	☐	☐	☐
5.d	Ne pouviez pas respirer facilement?	☐	☐	☐	☐
5.e	Toussiez ou ronfliez bruyamment?	☐	☐	☐	☐
5.f	Aviez froid?	☐	☐	☐	☐
5.g	Aviez trop chaud?	☐	☐	☐	☐
5.h	Aviez fait de mauvais rêves?	☐	☐	☐	☐
5.i	Ressentiez de la douleur?	☐	☐	☐	☐
5.j	Autres raisons. SVP décrivez et à quelle fréquence :	☐	☐	☐	☐
6.	**Durant le dernier mois, comment évalueriez-vous la qualité globale de votre sommeil?**	**Très bien** ☐	**Plutôt bien** ☐	**Plutôt mal** ☐	**Très mal** ☐
7.	**Durant le dernier mois, combien de fois avez-vous :**	**Pas durant le dernier mois**	**Moins 1 fois par semaine**	**1 ou 2 fois par semaine**	**3 fois ou plus par semaine**
7.a	Pris un médicament (avec ou sans ordonnance) pour vous aider à dormir?	☐	☐	☐	☐
7.b	Eu de la difficulté à rester éveillé pendant que vous conduisiez, mangiez, ou vous engagiez dans une activité sociale?	☐	☐	☐	☐
8.	**Durant le dernier mois, jusqu'à quel point avez-vous eu de la difficulté à maintenir suffisamment d'enthousiasme pour compléter vos activités?**	**Aucune** ☐	**Légère** ☐	**Quelque peu** ☐	**Beaucoup** ☐
9.	**Avez-vous un partenaire de lit ou de chambre?**				
9.a	Pas de partenaire de lit ou de chambre. ☐				
9.b	Partenaire ou colocataire dans une autre chambre. ☐				
9.c	Partenaire dans la même chambre, mais pas dans le même lit. ☐				
9.d	Partenaire dans le même lit. ☐				
10.	**Si vous avez un partenaire de lit ou de chambre, demandez-lui combien de fois dans le dernier mois vous avez :**	**Pas durant le dernier mois**	**Moins 1 fois par semaine**	**1 ou 2 fois par semaine**	**3 fois ou plus par semaine**
10.a	Ronflé bruyamment?	☐	☐	☐	☐
10.b	Eu de longues pauses entre les respirations pendant votre sommeil?	☐	☐	☐	☐
10.c	Eu des contractions ou secousses dans les jambes pendant votre sommeil?	☐	☐	☐	☐
10.d	Eu des épisodes de désorientation ou de confusion durant le sommeil?	☐	☐	☐	☐
10.e	Eu des agitations pendant que vous dormiez? SVP décrire et à quelle fréquence?	☐	☐	☐	☐

8.2 Appendix II: Orthodontic Evaluation Form

FORMULAIRE D'ÉVALUATION

1. Physique

1.a Origine : _____

1.b Hauteur : _____ + 100cm

1.c Poids : _____ lbs

2.	Facial	Convexe	Droit	Concave
2.a	Profil :	☐	☐	☐
		Brachy.	**Méso.**	**Dolico.**
2.b	Visage :	☐	☐	☐
		Fermé	**Normal**	**Ouvert**
2.c	FMA :	☐	☐	☐

2.d Lignes médianes :

3.	Fonctionnel	Buccale	Nasale	½ : ½
3.a	Respiration	☐	☐	☐

		Normales	Grosses
3.b	Amygdales	☐	☐

		Petite	Normale	Grosse	Crénelée
3.c	Langue	☐	☐	☐	☐

	ATM	Craquement		Douleur		Si Douleur, Combien?										
		Oui	Non	Oui	Non	0	1	2	3	4	5	6	7	8	9	10
3.d	Droite	☐	☐	☐	☐											
3.e	Gauche	☐	☐	☐	☐											

		Normaux	Anormaux
3.f	Mouvements Mand. Latéraux	☐	☐

3.g Overjet : _____ mm

3.h Overbite : _____ mm

3.i Ouverture Maximale (*avec OB*) : _____ mm

4.	Squelettique	Diminué	Normal	Augmenté
4.a	Transverse :	☐	☐	☐
4.b	Vertical :	☐	☐	☐
4.c	A-P :	☐	☐	☐
		Étroit	**Rond**	**Plat**
4.d	Palais	☐	☐	☐

5. Dentaire

	Classe	I	II	III
5.a	Molaire Droite	☐	☐	☐
5.b	Molaire Gauche	☐	☐	☐
5.c	Canine Droite	☐	☐	☐
5.d	Canine Gauche	☐	☐	☐

		Oui	Non
5.e	Crossbite	☐	☐

(Si oui, encerclez les dents en crossbite)

18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38

	Chevauchement ou Espace	Espace	Chevauchement		
			Léger (1-2mm)	Moyen (3-4mm)	Sévère (>5mm)
5.f	Maxillaire	☐	☐	☐	☐
5.g	Mandibule	☐	☐	☐	☐

	Courbes	Légère	Moyenne	Sévère	Inversée
5.h	Spee	☐	☐	☐	☐
5.i	Monson	☐	☐	☐	☐
5.j	Wilson	☐	☐	☐	☐

	Attrition	Non	Émail	Dentine
5.k	Incisives Supérieures	☐	☐	☐
5.l	Canines Supérieures	☐	☐	☐
5.m	Prémolaires Supérieures	☐	☐	☐
5.n	Molaires Supérieures	☐	☐	☐
5.o	Incisives Inférieures	☐	☐	☐
5.p	Canines Inférieures	☐	☐	☐
5.q	Prémolaires Inférieures	☐	☐	☐
5.r	Molaires Inférieures	☐	☐	☐

6. Tissus Mous

6.a Problèmes de paro.: _____

7.	Diagnostique	Classe I	Classe II	Classe III	Autres
7.a	Dentaire	☐	☐	☐	
7.b	Squelettique	☐	☐	☐	

		Non-Ex	Exo	P&I	Exp.	Chir.	Autres
8.	Traitement Proposé	☐	☐	☐	☐	☐	

		Accepté	Refusé
9.	Cas	☐	☐

	AP	HEK
Évalué par	☐	☐