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Pediatric Obstructive Sleep Apnea: A Comprehensive Review from a Pediatric Dentist's Perspective

Pediatrik Obstrüktif Uyku Apnesi: Pediatrik Diş Hekiminin Perspektifinden Kapsamlı Bir İnceleme

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ABSTRACT

Sleep is an important physiologic process that undergoes significant changes through the various developmental stages from early childhood through adulthood. Any disturbance to this physiologic process during childhood leads to impaired growth and development. Pediatric Obstructive Sleep Apnea (OSA) is a prevalent sleep-related breathing disorder affecting children which often goes undiagnosed leading to long-term systemic complications. In a multidisciplinary approach to diagnosing and treating this condition, pediatric dentists have been found to play a crucial role in early assessment. This is due to their ability to recognise various craniofacial signs and symptoms associated with the condition. These signs include jaw growth abnormalities and features such as a shortened lingual frenum and sleep bruxism. By conducting routine dental examinations in children, pediatric dentists are ideally situated to identify these indicators at an early stage. The role of a pediatric dentist is not limited to diagnosis. Still, it is attributed to various non-surgical treatment modalities that can modify the growth and development of the jaw bones thereby improving the condition and in preventing long-term complications. This narrative review emphasizes the role of pediatric dentists in the early identification of pediatric OSA and provides a comprehensive overview of evidence-based practices for managing these patients or referring them for further specialized care.

Keywords: Diagnosis, management, pediatric dentistry, sleep apnea

ÖZ

Uyku, bebekliğin erken dönemlerinden itibaren gelişen, çocukluk dönemine ilerleyen ve yetişkinlik öncesinde ergenliğe geçiş sürecinde önemli değişikliklere uğrayan önemli bir fizyolojik süreçtir. Çocukluk döneminde bu fizyolojik süreçteki herhangi bir bozulma, büyüme ve gelişmenin bozulmasına yol açar. Pediatrik Obstrüktif Uyku Apnesi (OSA), çocukları etkileyen, sıklıkla teşhis edilemeyen ve uzun vadeli sistemik komplikasyonlara yol açan yaygın bir uyku ile ilişkili solunum bozukluğudur. Pediatrik obstrüktif uyku apnesinin (OSA) tanı ve tedavisine multidisipliner bir yaklaşımla, pediatrik diş hekimleri erken değerlendirmede çok önemli bir rol oynamaktadır. Bunun nedeni, durumla ilişkili çeşitli kraniyofasiyal belirti ve semptomları tanıma yetenekleridir. Bu işaretler sadece çene büyümesi anormalliklerini değil aynı zamanda kısalmış lingual frenum ve uyku bruksizmi gibi özellikleri de içerir. Pediatrik diş hekimleri, çocuklarda rutin diş muayeneleri yaparak bu göstergeleri erken bir aşamada tespit etmek için ideal bir konumdadır. Pediatrik diş hekiminin rolü teşhisle sınırlı değildir; çene kemiklerinin büyümesini ve gelişimini değiştirebilen, böylece durumu iyileştirebilen ve uzun vadeli komplikasyonları önleyebilen çeşitli cerrahi olmayan tedavi yöntemlerine atfedilir. Bu makalenin amacı Pediatrik Obstrüktif Uyku Apnesinin (OSA) erken teşhisinde pediatrik diş hekimlerinin rolünü incelemek ve bu hastaların tedavisi veya daha ileri müdahale için sevk edilmesi için en iyi kanıta dayalı uygulamaların kapsamlı bir incelemesini sunmaktır.

Anahtar kelimeler: Tanı, tedavi, çocuk diş hekimliği, uyku apnesi

INTRODUCTION

Sleep is characterized as a reversible, physiologic and recurring behavioural state marked by reduced awareness of the surrounding environment and decreased responsiveness to external stimuli.[1] Sleep is a dynamic process that plays a pivotal role in fostering optimal brain growth and development, strengthening immune function, and physiological and neuro-cognitive functions.[2] However, any alterations in this dynamic process lead to deteriorated neurocognitive development and ability, physiological impairment and heightened systemic inflammation, thereby affecting the quality of life.[1,2]

The current iteration of the International Classification of Sleep Disorders (ICSD-3) categorizes sleep disorders into seven distinct domains: insomnia, sleep-disordered breathing (SDB), central

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hypersomnolence, circadian rhythm sleep-wake disorders (CRSWD), parasomnias, sleep-related movement disorders (SRMD), and isolated symptoms. Notably, the ICSD-3 establishes diagnostic benchmarks applicable to both pediatric and adult populations across the developmental spectrum.[3] Furthermore, age-specific criteria are provided for chronic insomnia, quiescent sleep (Non-Rapid Eye Movement) parasomnias, SRMDs, and SDBs.[3,4] Within this spectrum, Obstructive Sleep Apnea (OSA) emerges as the most prevalent form of developmental SDB.[1-4]

OSA is characterized by airflow cessation (Apnea); airflow reduction (hypopnea) is a breathing disorder diagnosed across age groups from infants to older adults. Pediatric OSA was initially described by Gulliminault [11] in children who had described symptoms of disruption of airflow in sleep, snoring, traits including altered school performance, sleepiness, morning headache, abnormal weight gain and enuresis during daytime, with associated evidence of polysomnographic findings analogous to adult OSA.[1,2,4] However, this condition often remains undiagnosed due to the varied consensus in diagnostic criteria and the lack of explicit symptoms that patients or parents can report.

The evolution of the new interdisciplinary field of dental sleep medicine has paved the way for the early identification of pediatric OSA conditions, wherein the scope has expanded from orthodontists and pediatric dentists to general dentists.[5] Though pediatric OSA cannot be entirely diagnosed by pediatric dentists, they play a significant role in screening children with increased risk of OSA and often in referring children to specialists for definitive diagnosis.[4,5] This could be attributed to the fact that pediatric dentists examine children more frequently than other specialities.[5-7] Various craniofacial features associated with pediatric OSA can be promptly assessed by dentists, which predominantly results in timely identification. Of the debilitating condition and prevent long-term effects such as cor-pulmonale, failure to thrive and neurocognitive defects.[1,2,6,8] Pediatric dentists have proven to be an essential part of early intervention of the condition in addition to its diagnosis, thereby manifesting the need for an ambidextrous approach.[4,5]

EPIDEMIOLOGY

Sleep-related problems are frequently reported in 25-40% of pre-schoolers and school-aged children, including conditions such as insomnia, OSA, Restless Legs Syndrome, sleep talking (somniloquy), bedwetting (enuresis), rhythmic movements, and arousal disorders.[7,9]

SRDB in children has a spectrum of symptoms which ranges from primary snoring to pediatric OSA. The prevalence of pediatric OSA ranges from 1 to 4%.[10,11] According to a study conducted in Türkiye, primary snoring had a prevalence rate of 7.2%.[12]

Pediatric OSA is common among children aged 2 to 7 years. The reason attributed to this age range is the increased size of the lymphatic tissue of the upper airway,[9,13] with a greater male predilection and children with increased Body Mass Index (BMI)[9-11] and the second peak emerges during adolescence with regards to obesity[6]. OSA in children is also found to be associated with other neurocognitive defects such as attention-deficit hyperactivity disorder, excessive daytime sleepiness, poor academic performance and bruxism, demonstrating its need for expeditious diagnosis and treatment planning.[8,9] There is also a significant difference in prevalence seen in the aspect of race and ethnicity, where there is an increased prevalence in African children when compared to American children.[9,11]

Habitual snoring, which is recognised as an important manifestation of pediatric OSA, has a prevalence range from 3.2% to 12.1% with a positive correlation to a range of daytime and night-time symptoms, which include daytime mouth breathing, restless sleep, hyperactivity, tooth grinding, and nocturnal enuresis.[14] When comparing the patterns of snoring, the prevalence of “Habitual” snoring ranged from 9.6%-21.2%, and the prevalence of snoring “Always” ranged from 3.6% to 7.7%.[9]

Excessive daytime sleepiness is prevalent among children with OSA. The prevalence of daytime sleepiness ranges from about 7% with the mean prevalence of mild OSA to severe OSA among school-age children ranging from 9.5% to 1.6% respectively, more specifically among children in elementary levels.[15]

A strong association is exhibited between sleep bruxism and pediatric OSA, with a prevalence of sleep bruxism to be 21% which is highest in children of age group 5-7 years, with a direct effect on daytime problematic behaviour.[16]

Pediatric OSA has been strongly associated with poor academic performance, with a prevalence of 9.6% reported among Indian children.[17] A long-term follow-up study further highlights the correlation between OSA and declined academic performance.[18] There is also a positive correlation exhibited between nocturnal enuresis and poor academic performance and factors such as sleep bruxism and sleep talking have independently been associated with pediatric OSA, thereby affecting the quality of life.[16-19]

CLINICAL FEATURES

The often-observed symptoms of pediatric OSA are snoring in addition to noisy breathing.[18] Patients who snore loudly three or more evenings per week typically have OSA symptoms, outside the context of upper respiratory tract infections. However, there is a significant variation in the pattern of snoring among children and adults. In adults, the prevalence of OSA is characterized by intermittent snoring alternating with periods of paused breathing. In contrast, children typically exhibit a continuous snoring pattern due to prolonged airway obstruction, differing from the adult snoring pattern. While the breathing pattern in children with OSA varies significantly, common symptoms include mouth breathing, gasping, and snorting sounds. Shallow breathing and atypical breathing patterns during sleep are also clinical features that often alarm parents, who may feel the need to wake their child from sleep.[20-22]

There are other additional non-obvious symptoms associated with OSA. Children may frequently be sleep prone, with their neck extended, or in other positions that reduce obstruction, such as stacked with multiple pillows.[21] Other frequent symptoms in children with clinically significant OSA include excessive morning somnolence, learning disorder, and reduced cognition, which may be of chief concern. The clinician should perform a behavioural and learning problem assessment in addition to screening for daytime sleepiness, with a focus on classroom performance.[15,16] Children who exhibit severe nocturnal hypoventilation may experience carbon dioxide retention-related early morning headaches. Primary monosymptomatic nocturnal enuresis also has a strong correlation with pediatric OSA.[11,22]

Pediatric OSA is further classified into three distinct types based on the etiological factors as[8]

TYPE I – Pediatric OSA associated with marked lymph adenoid hypertrophy in the absence of obesity.

TYPE II - Pediatric OSA associated primarily with obesity and with milder upper airway lymph adenoid hyperplasia.

TYPE III – Pediatric OSA associated with syndromic conditions.

The various signs and symptoms of type I and type II are described in table -1

In addition, pediatric OSA cases exhibit unique craniofacial characteristics concerning facial height, the association of the jaws, and upper airway dimensions. These craniofacial features, as described in Table 2, should be considered as risk factors for the assessment of pediatric OSA when associated with medical history indicating sleep problems.[1,2,5,6]

Table 1. Signs and Symptoms associated with Type I and Type II POSA[8]

S.No	Symptom/Finding	OSA Type - I	OSA Type - II
1.	Excessive daytime sleepiness	✓	✓✓✓✓
2.	Weight gain	**X**	✓✓
3.	Hyperactive behaviour	✓✓✓✓	**X Or** ✓
4.	Attention problems	✓✓✓✓	✓✓✓
5.	Truncal/visceral obesity	X **Or** ✓	✓✓✓
6.	Enlarged neck circumference	**X Or** ✓	✓✓✓
7.	Enlarged tonsils/adenoids	✓✓✓✓	✓✓
8.	Recurrent otitis media/tympanostomy tube placement	✓✓✓	✓
9.	Depression and low self-esteem	✓	✓✓✓
10.	Shyness and social withdrawal	✓	✓✓✓
11.	Left ventricular hypertrophy	✓✓	✓✓✓✓
12.	Systemic hypertension/altered blood regulation	✓	✓✓✓✓
13.	Insulin resistance	**X**	✓✓✓✓
14.	Serum lipid abnormalities	✓	✓✓✓✓
15.	Elevated C-reactive protein	✓✓	✓✓✓✓
16.	Elevated Liver enzymes	X	✓✓

- ✓ indicates the presence of a symptom/finding.
- ✓✓✓✓ indicates a higher severity or frequency.
- ✗ indicates the absence of a symptom/finding.
- ✗ or ✓ indicates the symptom/finding may or may not be present

Table 2. Craniofacial Characteristics associated with Pediatric OSA[1,2,6]

S.No	Extraoral features	Intraoral features
1	Increased total and lower facial height	High arched palate/Narrower maxilla
2	Retrusive mandible or retrognathia	Decreased inter-tooth distance between the first, and second deciduous molars and permanent first molars
3	Deficient chin or micrognathia	Enlarged soft palate
4	Midfacial hypoplasia	Macroglossia
5	The inferior position of the hyoid bone	Ankyloglossia
6	Decreased mandibular width.	Posterior crossbite
7	Labial incompetency	Anterior open bite
8	Increased Cervicomental angle	High arched palate/Narrower maxilla

EXAMINATION

A focused sleep history acts as a highly effective adjunct to the clinical evaluation. The history mainly involves questioning parents on the children's quality of sleep, subsequently, more detailed inquiries about the nature of other sleep disturbances are also evaluated.[21]

If not particularly questioned, parents seldom mention issues about their child's sleep problems. When prompted, parents frequently admit that their kids snore, but they frequently add a warning that it only happens when the child has an upper respiratory illness or is congested. However, aided questioning involves whether the child exhibits any additional symptoms of sleep disturbances. Parents may mention snoring that is intertwined with periods of frank obstruction or breathing pauses when they can specifically explain the unsettling nocturnal breathing patterns in their children. Older kids and teenagers might say that a cough or a frightened, choking feeling caused them to awaken from a nap. Parents may notice stridor, gasps, retractions, or apnea along with clearly difficult breathing when a child snores loudly. These audible overt apneas are frequently called "choking" events. Parents may be unaware that many children with OSA experience hypopneas or blocked hypoventilation.[19,20] Daytime concerns including academic performance, behaviour, concentration, and sleepiness, are other factors that should also be addressed during further assessment.[14,21,23]

Central obesity, excess cervical musculature and other indicators of metabolic disorder or insulin resistance, such as acanthosis nigricans, indicate a link between obesity-related OSA and concurrent metabolic disorders. Alternately, young infants with OSA fail to thrive due to the increased energy expenditure required to overcome airway obstructions. Fingertip clubbing, frequently linked to chronic hypoxemia and hypoventilation, can be a sign of underlying lung disease.[21]

Assessment of circumference of the neck (NC), neck-to-waist ratio (NW), and neck-to-height ratio (NH) is crucial for predicting pediatric OSA in children with obesity. These measurements are significant risk factors, as airway obstruction is often exacerbated by greater tissue mass over the airway, leading to the closure of airway space. An increase in NC by 95 percent has been linked to a higher risk of OSA and has been shown to predict OSA more accurately than BMI in older children, particularly those who are not predominantly obese. Children with higher NC, and NW ratio has been associated with increased OSA risk. The NH ratio is also considered a valuable predictor of OSA, assessing the distribution of body fat relative to overall adiposity.[13,22]

ASSESSMENT OF CRANIOFACIAL FEATURES

Understanding how subtle abnormalities of a child's teeth, jaw, tongue, adenoids, palate and tonsils interact to contribute to the obstruction of the upper airway is crucial during the physical examination of patients suspected of having OSA.[23] When a child sleeps, the tongue and muscles supporting the soft palate relax, potentially obstructing the upper airway, especially when sleeping on their back. It's recommended to evaluate both tonsil size and Mallampati classification (Figure 1) during oropharyngeal assessment, as these factors are linked to OSA severity. Tonsillar hypertrophy can be assessed using the Brodsky and Friedman scales (Figure 1).

The FAIREST-6 scale (Figure 2) is a valuable clinical tool for evaluating functional, extraoral, intraoral soft tissue, and intraoral hard tissue factors. It evaluates parameters such as nasal breathing, mentalis strain, tonsil size, ankyloglossia, tooth wear, and dental crowding. These features should be considered alongside medical history, and children should undergo diagnostic evaluations for accurate diagnosis.[24] The American Academy of Pediatric Dentistry (Figure 3) has developed a screening form to identify children at increased risk of pediatric OSA.[13]

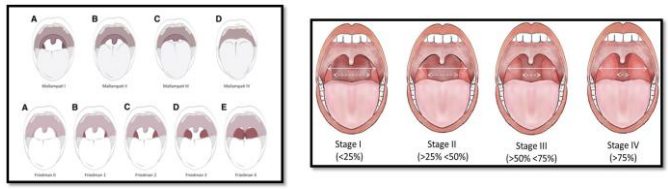

Figure 1. Mallampati, Friedman scale and Brodsky Scale[21]

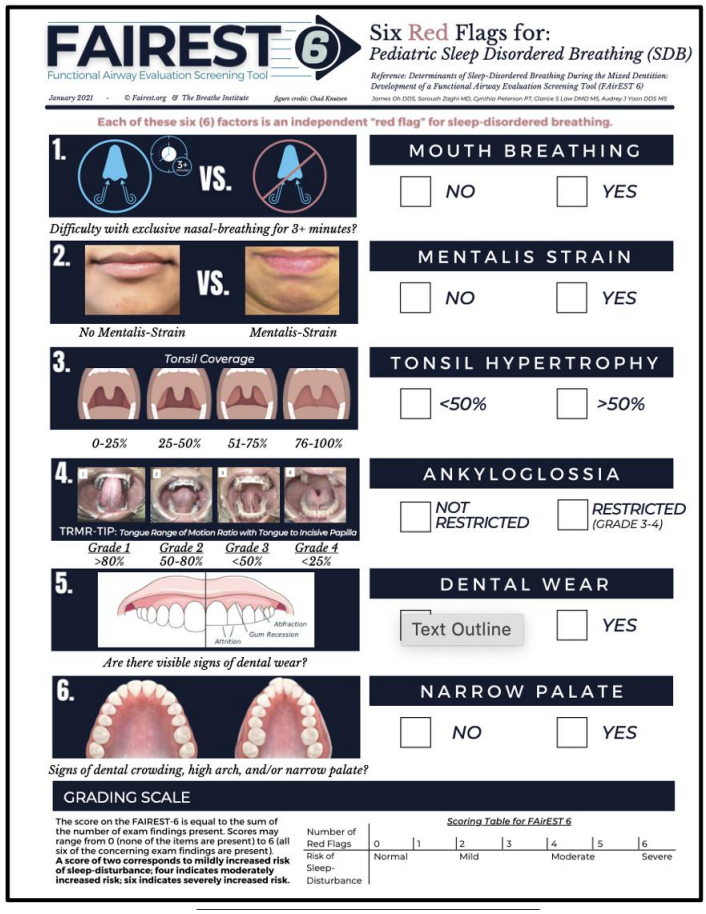

Figure 2. FAIREST-6 Scale[24]

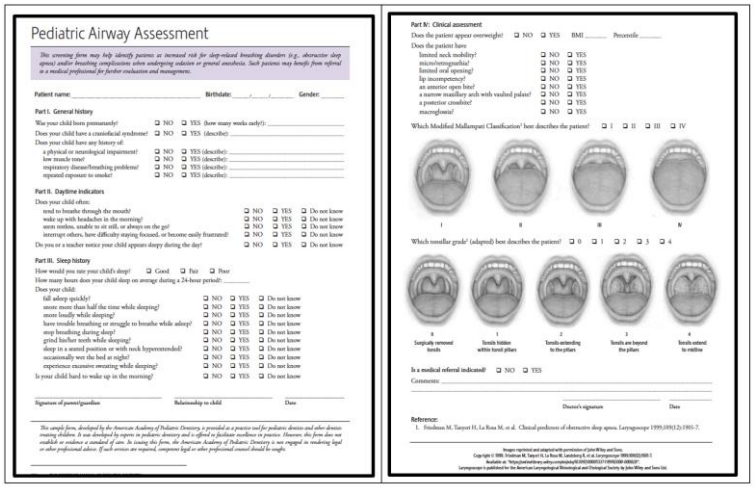

Figure 3. AAPD- Pediatric airway assessment form[13]

ASSOCIATION BETWEEN PEDIATRIC OBSTRUCTIVE SLEEP APNEA AND MOUTH BREATHING HABIT

Mouth breathing affects more than 55% of children aged 3–9 years[25] and is frequent in 41% of children with OSA.[26] Mouth breathing is a parafunctional habit prevalent among children and often indicates the presence of SDB, characterized to be associated with habitual snoring and OSA, however, the etiological factors of mouth breathing, apneic hyopnic index are major determinants that should be assessed to differentiate mouth breathing habits associated with pediatric OSA.[25,26]

BRUXISM AND PEDIATRIC OBSTRUCTIVE SLEEP APNEA

Children who exhibit symptoms of bruxism should also be evaluated for sleep apnea, as a strong connection has been found between bruxism and pediatric OSA.[16,19,27]

Sleep bruxism is often linked with other sleep disturbances such as snoring, and movements during sleep associated with daytime behavioural issues, necessitating an interdisciplinary approach when assessing bruxism and pediatric OSA in children.[16]

Clinical diagnostic parameter for sleep bruxism:[28]

Patient History

Recent reports from patients, parents, or siblings indicate tooth grinding sounds during sleep occurring at least 3–5 nights per week over the past 3–6 months.

Diagnostic assessment of sleep bruxism includes

- Aberrant tooth surface loss,
- Increased tonicity of the masseter muscles on voluntary forceful biting,
- Distress, fatigue, or tender jaw muscles (temporary temporomandibular muscle pain and headache in the morning).

Children with wear facets on the tooth surface (as evaluated by the dentist) are linked with a higher risk of sleep bruxism. It is frequently evident in children that deciduous teeth have decreased mineral density compared to permanent teeth. Nonetheless, the presence of tooth tissue wear on hard surfaces alone does not constitute a clinical diagnosis of sleep bruxism.[28]

SHORTENED LINGUAL FRENUM AND PEDIATRIC OBSTRUCTIVE SLEEP APNEA

Among the numerous risk factors for OSA in children, such as obesity, inflammation of adenoids, and tonsils, allergic rhinitis and septal deviation, a shortened lingual frenulum is associated with increased upper arch collapsibility and contributes to the development of pediatric OSA.[29] An untreated short lingual frenulum at birth is linked to a greater risk of OSA later in life,[30] highlighting the importance of systematic examination when this anatomical abnormality is detected.

Children at risk of OSA often have a short lingual frenulum associated with head-forward posture (HFP), a high-arched palate, and malocclusion.[31] Therefore, children with SDB should be evaluated for a short lingual frenulum, and conversely, those with an abnormally short frenulum should be investigated for the presence of SDB.[30-32] This emphasizes the need for a multidisciplinary approach to correct pediatric OSA associated with a shortened lingual frenulum.[32]

ORAL HEALTH AND PEDIATRIC OBSTRUCTIVE SLEEP APNEA

A strong correlation between pediatric OSA and dental caries in children has been reported in studies.[5,6] Literature has also reported poor oral health in children affected with OSA with increased incidences of gingivitis and periodontitis, thereby impacting the oral-health-related quality of life. This emphasises the role of a pediatric dentist in the assessment of obstructive breathing patterns in children with high caries risk and poorer oral health.[6]

DIAGNOSTIC AIDS

American Academy of Sleep Medicine diagnostic indicators for pediatric OSA includes:[33,34]

A. The presence of one or more of the following:

1. Snoring
2. Laboured, unusual, or impaired respiration when the child sleeps.
3. Somnolence, restlessness, behavioural issues, or difficulties with cognition.

B. Polysomnography findings involve at least one of the listed symptoms:

1. More than one instance of obstructive or mixed apneas, or obstructive hypopneas, per hour of sleep.
2. A pattern of impaired respiration, identified by experiencing hypercapnia (*$PETCO_2$ > 50 mm Hg) for at least 25% of total sleep time and/or arterial oxygen desaturation, along with one or more of the following symptoms: snoring, inconsistent chest-abdominal motion flattening of the inspiratory nasal pressure waveform.

*$PETCO_2$ - End-tidal CO_2 Tension.

Diagnosis requires the presence of signs and symptoms from Category A and Category B.

Overnight polysomnography (PSG) is the definitive method for diagnosing and determining the intensity of pediatric OSA. With a few exceptions, the physiologic parameters typically measured during pediatric PSG are identical to those measured during adult PSG.[33,34]

The objective of PSG is to:[33]

(i) Detect, distinguish, and measure obstructive apneas, mixed apneas, and central apneas.

(ii) Identify and categorize hypopneas and high resistance syndromes to assess sleep interruptions.

Though it remains the definitive diagnostic aid for this condition,[5] it often has low accessibility with a high cost and is highly time consumable, thereby delaying appropriate diagnosis and treatment. This may also be attributed to the limited research available with larger samples.[34]

Various other investigative modalities used for the assessment of pediatric OSA include the home PSG, pulse oximetry, radiographic examination, which includes chest X-ray and lateral cephalograms, drug-induced sleep endoscopy, computed tomography, and magnetic resonance imaging techniques.[35]

Sleep Questionnaires:

Although PSG is regarded as the standard criterion for diagnosing pediatric OSA, due to its several shortcomings such as high associated cost, less accessibility and complicated process, it has limited effectiveness in the assessment of pediatric OSA.[33,36] Over the last few decades, the rapid and dynamic growth of pediatric sleep research has necessarily resulted in the development and adoption of a variety of survey tools that have facilitated significant discoveries and the overall advancement of the discipline.[36,37] Several sleep questionnaires have been developed, with the most widely utilized ones being for assessing pediatric OSA, are described in Table 3.[37-40]

Table 3. Commonly Used Pediatric Sleep Questionnaires for Assessment of Pediatric OSA

S.No	Questionnaire	Author and Year	Features assessed	Grading system	Clinical significance
1.	Pediatric Sleep Questionnaire (PSQ)	Chervin et al in 2000	Three prominent symptom complexes -snoring, excessive daytime sleepiness, and inattentive/hyperactive behaviour.	It contains 22 close-ended questions (answers are "yes" or "no"). A set of 8 or more affirmative answers is considered a positive result	Nocturnal and diurnal symptoms of obstructive SDB; can be assessed. PSQ is easy to administer at a medical facility, does not take more than 15 minutes and does not require an engaging physician or specially trained personnel. Sensitivity and Specificity 78% and 72%
2.	OSA-18	Franco et al in 2000	Sleep disturbance, physical symptoms, emotional distress, daytime function, and caregiver concerns.	The 18 survey items are scored using a Likert-type scoring system with a 7-point scale. A total score system(TSS) may vary 18-126 points.	The caregiver is asked to report how often during the previous four weeks their child has had specific symptoms using the following response scale. A TSS at or above 60 is considered abnormal and is associated with SDB. Scores of 60–80 suggest a moderate impact on the disease-specific quality of life and a score above 80 suggests a large impact.
3.	I'M SLEEPY	Kadmon et al. in 2014	Short and sensitive screening tool which facilitated accurate triage.	It is an 8-item questionnaire, designed in a yes/no format for simplicity of completion and scoring	This included both the parent and the child's version, where the parent version was filled by parents for children below 7 years of age and the child's version was filled by the child aged above 7 years of age. However, it is sensitive (82%), but less specific (50%) for the diagnosis of OSA.
4.	OSA-5	Soh JH et.al in 2018	5 item triage questions derived from a validated 11-item questionnaire developed by the authors for screening a large number of children	If a child scores under 5 on the 5-item questionnaire (total possible score of 15), they are unlikely to have significant OSA and could reasonably be observed for 3-6 months to determine the progress of symptoms.	The score however had a low specificity, with a large false positive rate.
5.	Sleep Disturbances Scale for children	Bruni et al in 1996	Two sections: Section 1 - demographic, behavioural and clinical data, information about previous illnesses and present medical status with specific questions regarding pathology that could affect sleep, Section -2 is the sleep questionnaire	Made up of 27 items in a Likert-type scale with values 1-5 with the wording arranged so that higher numerical values reflected a greater clinical severity of symptoms	
6.	Children's sleep abits questionnair	Owens et al., in 2000	Bedtime behaviour and sleep onset; sleep duration; anxiety around sleep; behaviour occurring during sleep and night waking; sleep-disordered breathing; parasomnias; and morning waking/daytime sleepiness	Items are rated on a three-point scale: "usually" if the sleep behaviour occurred five to seven times/week; "sometimes" for two to four times/week; and "rarely" for zero to one time/week.	Parents are asked to recall sleep behaviours occurring over a "typical" recent week. This questionnaire had a sensitivity of 89% and a specificity of 74%
7.	6Q questionnaire	Masoud et.al in 2020	Set of 6 hierarchically arranged questions as a sub-set of the 22-item PSQ		The 6Q showed statistical significance, while the more commonly used PSQ did not, both in terms of correlating with AHI and predicting moderate and severe sleep apnea.

Imaging techniques

The lateral neck radiography imaging technique is straightforward, widely available, and cost-effective. It allows assessment of the oral and nasal airways, epiglottis, trachea, soft tissue in front of the vertebrae, nasopharynx, tonsils, and adenoids (Figure 4). The most studied radiographic parameter is the adenoidal-nasopharyngeal ratio. However, these images are obtained with the patient awake in a standing or sitting in a straight and vertical orientation, typically with the spine erect.[35]

Cone-beam computed tomography is the most used diagnostic imaging approach for the initial assessment of OSA in children, by assessing the size of the tonsils and adenoids (Figure 4). It is considered a straightforward, reliable, and non-invasive diagnostic instrument capable of visualizing both the complete structure and transverse section of the nasopharyngeal airway. It aids in measuring adenoid and airway size in children with adenoid enlargement.[35,41]

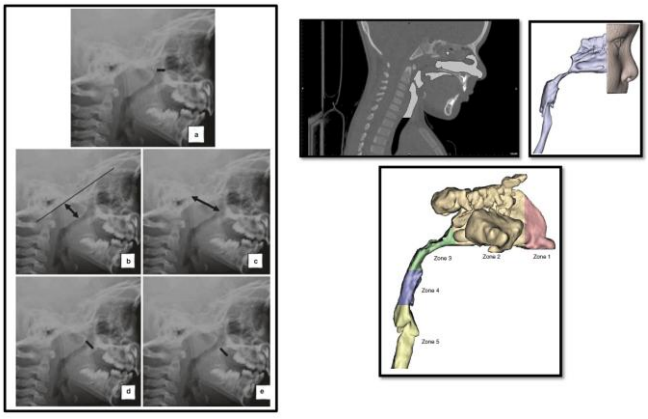

Figure 4. Imaging techniques-lateral cephalogram, computed tomography for assessment of oropharyngeal structures[35]

TREATMENT PLANNING

The varied treatment options proposed for the treatment of pediatric OSA include[42,43]

1. Surgical management
   a. Adenotonsillectomy
   b. Nasal and Nasopharyngeal Surgery
   c. Oropharyngeal Surgery
   d. Surgery to correct tongue base collapse.
2. Non-Surgical management
   a. Pharmacological management (Anti-inflammatory therapy)
   b. Orthodontic management
      i. Maxillary expansion
      ii. Mandibular advancement
   c. Oral Myofunctional Therapy

Treatment of OSA should aim to create adequate ventilation space, enhance craniofacial growth, alleviate all symptoms, and prevent the progression to adult OSA. Children with alleged symptoms of pediatric OSA should be referred to a specialist in sleep medicine or an otolaryngologist. The specialist later performs PSG where clinically relevant apnea-hypopnea index and other relevant systemic symptoms related to pediatric OSAS are determined[43] for appropriate management of the condition as described in Figure 5.

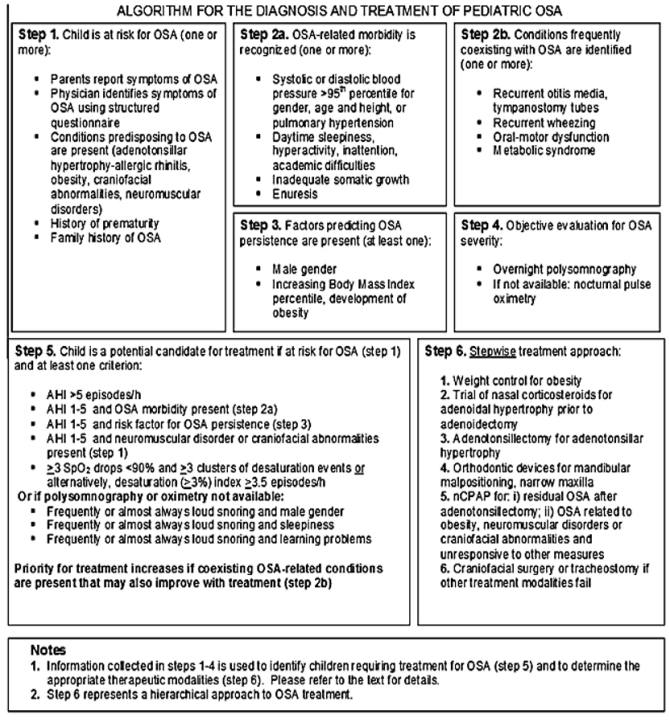

Figure 5. Algorithm for diagnosis and treatment of Pediatric OSA[43]

Dentists can serve as an indispensable part of the interdisciplinary team for managing children with pediatric OSA. Various craniofacial treatment methods have been studied for children with pediatric OSA, including rapid maxillary expansion, mandibular advancement devices, and surgeries for correction of jaws (for patients who have achieved complete craniofacial development). Some of these treatments are proposed as alternatives to surgical intervention. These options should also be explored for cases where residual OSA continues following adenotonsillectomy.[5,6]

Surgical Management

The initial treatment proposed for children with pediatric OSA is adenotonsillectomy.[42,43] Tonsillectomy entails the excision of the tonsils, including their underlying capsule, and is considered the standard practice throughout the years.[42] The childhood adenotonsillectomy trial was an important randomized control trial which aimed at assessing focus on sleep quality, cognitive and behavioural outcomes, growth, and cardiovascular health and the long-term outcomes in children treated with AT, and watchful waiting with supportive care (WWSC) for pediatric OSA. Considering that certain children may derive greater benefit from WWSC than from interventions, this approach can assist healthcare providers and parents in selecting the most appropriate therapy for their child. The diagnosis and treatment of childhood OSA would fundamentally change if the parameters could be used to organize care in advance.[42]

NON-SURGICAL MANAGEMENT

PHARMACOLOGICAL MANAGEMENT

Anti-inflammatory drugs, such as oral montelukast and nasal corticosteroids, prevent the induction of inflammatory processes and the migration of inflammatory cells into the airways.[43] Nasal

corticosteroids and oral montelukast therapy were found to be significant in the management of mild to moderate pediatric OSA.

ORTHODONTIC MANAGEMENT

Rapid Maxillary Expansion

The narrow and long-faced facial structure, the highly curved palates, and the degree of mandibular retrusion all contribute to OSA's narrowing of the upper airway**.** Maxillary constriction can also lead to increased nasal resistance, decreased airflow, and changes in tongue posture, thereby reducing the posterior airway space.[44] Rapid maxillary expansion (RME) is recognized as a potent management modality for constricted hard palate, associated with OSA (Figure 6). RME is recommended for correcting skeletal transverse maxillary discrepancies, particularly in cases of maxillary constriction or posterior dental/ skeletal crossbite.[43] When RME is applied, it exerts pressure on the maxillary suture by using anchor teeth, leading to expansion of the palate. Children treated with RME have shown a substantial improvement in their apnea-hypopnea index thereby improving the oxygen saturation, according to studies.[44,45] RME acts by improving the apnea-hypopnea index, increasing the oxygen saturation and sleep efficiency by increasing the airway volume and oropharyngeal space and modifying the resting position of the tongue.[45-48] With the aetiology associated with adenotonsillar hypertrophy, RME is shown to markedly decrease the size of adenoids and tonsils, thereby improving symptoms of pediatric OSA.[46] Concerning the duration of the outcome, many studies have reported that there was an improvement of 73% in the AHI index in children with pediatric OSA after ≤ 3 years of follow-up and a 77% improvement in those with OSA after > 3 years of follow-up. RME acts as an effective appliance that not only corrects the maxillary constriction as well as severe nasopharyngeal space constrictions associated with mouth breathing and snoring in children,[45,46] and also acts as an effective orthodontic appliance for long-term stability and maintenance of expansion of maxillary arch.[48]

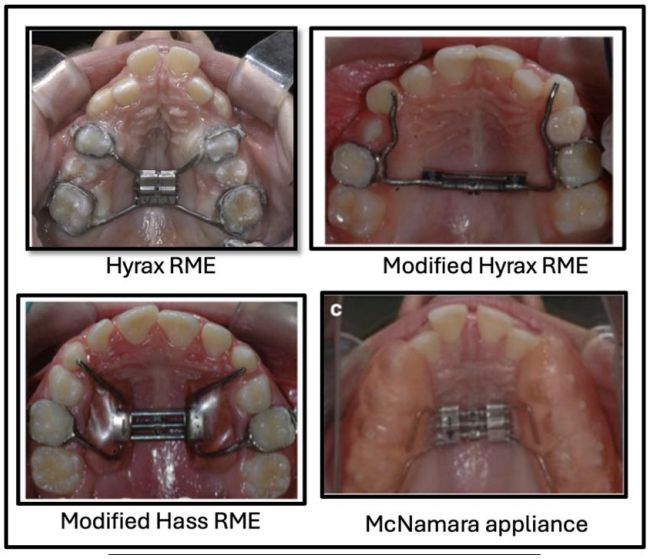

Figure 6. Rapid maxillary expansion devices[5]

Mandibular Advancement Devices

Mandibular retro position caused by abnormal mandibular development and malocclusion predisposes patients to upper airway collapse during sleep by affecting the skeletal components involved in respiratory mechanisms. Additionally, the mandibular retro position has been associated with posterior tongue base change, which further constricts the upper airway.[49] The mandibular advancement devices are a range of fixed or removable devices used in patients with retruded mandible (Figure 7).[5] These appliances are thought to improve the growth of the mandible by repositioning the mandible forward.

This action enlarges the anteroposterior dimension of the oropharyngeal area and decreases airway collapsibility.[5,49] This action is mainly influenced by the anterior positioning of the tongue, thereby increasing the space in the ventral aspect of the oropharynx. These appliances reposition the hyoid bone, widen the oropharyngeal airway in the ventral aspect, and activate the oropharynx dilator muscles[6]. Various devices such as Monobloc, Herbst, and Twin Block, have been suggested for mandibular advancement.[5,48-50] These devices have shown a significant improvement in sleep patterns, including enhanced sleep onset and continuity[50,51] and increase in sleeping time in the supine position, thereby providing a favourable airway geometry and increasing the lung volume. A study from Turkey demonstrated that treatment with monobloc appliances led to enhanced sleep quality, social behavior, and cognitive skills in children with pediatric OSA.[51]

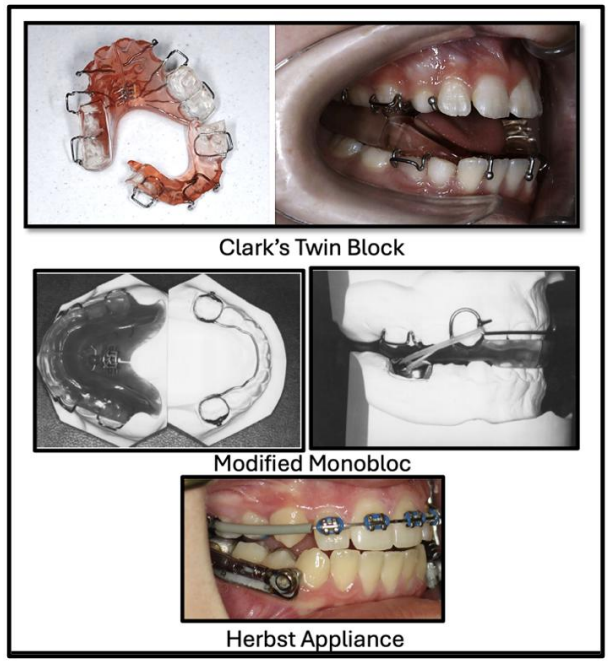

Figure 7. Mandibular advancement devices[5]

Myofunctional Therapy

The normal position of the orofacial muscles and tongue during sleep cannot be achieved only through correction of the upper airway. Persistent oral breathing while sleeping directly affects the strength and position of the tongue, and orofacial muscle development, potentially resulting in abnormal airway development. Myofunctional therapy is necessary to address these issues.[52] Orofacial myofunctional therapy (OMT) involves treating muscle dysfunctions in the face and mouth to improve or correct functions like chewing and swallowing and encourage nasal breathing.[53] Utilizing OMT, described in Table 4, as a non-invasive treatment option for pediatric OSA is a novel

application of this established therapeutic approach. It holds promise as a significant alternative to existing nonsurgical treatments like positive airway pressure and oral appliances. The exercises focus on promoting nasal breathing, ensuring proper lip closure, and reinforcing optimal tongue posture. This involves retraining the tongue to maintain a high position during sleep, with its tip consistently touching the palatal rugae on the front of the palate. This approach is particularly recommended for children aged six and older, where adherence by both the child and parents significantly influences therapy outcomes.[54]

Table 4. Myofunctional Therapy Exercises[49,50]: Myofunctional therapy has four basic components which include restoring proper rest oral posture, repatterning of facial muscle, teaching proper chewing and swallowing and functional posture training

S.No		Exercise	
1	Soft palate	The child is asked to pronounce an oral vowel intermittently (isotonic exercise) and continuously (isometric exercise).	These exercises had to be repeated daily for 3 minutes and were performed once a week under supervision to ensure adequate effort
2	Tongue	Brushing the superior and lateral surfaces of the tongue while the tongue is positioned on the floor of the mouth	Five times each movement, three times a day
		Placing the tip of the tongue against the front of the palate and sliding the tongue backward	A total of 3 min throughout the day
		Forced tongue sucking upward against the palate, pressing the entire tongue against the palate	
		Forcing the back of the tongue against the floor of the mouth while keeping the tip of the tongue in contact with the inferior incisive teeth	
3	Facial	Orbicularis oris muscle pressure with mouth closed (isometric exercise)	Recruited to close with pressure for 30 seconds,
		Suction movements contracting only the buccinator. These exercises were performed with repetitions (isotonic) and holding positions (isometric).	
		Recruitment of the buccinator muscle against the finger that is introduced in the oral cavity, pressing the buccinator muscle outward.	
		Alternated elevation of the mouth angle muscle (isometric exercise) and after, with repetitions (isotonic exercise).	10 intermittent elevations should be performed for three times
		Lateral jaw movements with alternating elevation of the mouth angle muscle (isometric exercise)	
4	Stomatognathic functions 1. Breathing and speech	(1) Forced nasal inspiration and oral expiration in conjunction with phonation of open vowels, while sitting	
		(2) Balloon inflation with prolonged nasal inspiration and then forced blowing	Repeated 5 times without talking balloon out of the mouth
	2.Swallowing and Chewing	Alternate bilateral chewing and deglutition, using the tongue in the palate, and closed teeth, without perioral contraction, whenever feeding	Incorporate this mastication whenever eating

CONCLUSION

Pediatric OSA is a common condition in children that often goes undiagnosed due to limited pediatric PSG facilities. If neglected, it can result in various health-related and behavioural issues in children like concentration issues, heightened activity levels, restlessness, and low academic performance. Long-term consequences include cardiovascular, metabolic, neurocognitive, and psychological problems, significantly impacting quality of life. A transdisciplinary approach involving otorhinolaryngologists, sleep specialists, neurologists, pediatricians, and oral surgeons aids in early detection through increased awareness and comprehensive screening. Including pediatric dentists in this interdisciplinary approach can aid in the timely identification and early intervention of pediatric OSA.[13]

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