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Missing teeth and pediatric obstructive sleep apnea

Christian Guilleminault[1] · Vivien C Abad[1] · Hsiao-Yean Chiu[1] · Brandon Peters[1] ·
Stacey Quo[2]

Abstract

Background Missing teeth in early childhood can result in abnormal facial morphology with narrow upper airway. The potential association between dental agenesis or early dental extractions and the presence of obstructive sleep apnea (OSA) was investigated.

Methods We reviewed clinical data, results of polysomnographic sleep studies, and orthodontic imaging studies of children with dental agenesis ($n = 32$) or early extraction of permanent teeth ($n = 11$) seen during the past 5 years and compared their findings to those of age-, gender-, and body mass index-matched children with normal teeth development but tonsilloadenoid (T&A) hypertrophy and symptoms of OSA ($n = 64$).

Results The 31 children with dental agenesis and 11 children with early dental extractions had at least 2 permanent teeth missing. All children with missing teeth ($n = 43$) had clinical complaints and signs evoking OSA. There was a significant difference in mean apnea-hypopnea indices (AHI) in the three dental agenesis, dental extraction, and T&A studied groups ($p < 0.001$), with mean abnormal AHI lowest in the pediatric dental agenesis group. In the children with missing teeth ($n = 43$), aging was associated with the presence of a higher AHI ($R^2 = 0.71$, $p < 0.0001$).

Conclusion Alveolar bone growth is dependent on the presence of the teeth that it supports. The dental agenesis in the studied children was not part of a syndrome and was an isolated finding. Our children with permanent teeth missing due to congenital agenesis or permanent teeth extraction had a smaller oral cavity, known to predispose to the collapse of the upper airway during sleep, and presented with OSA recognized at a later age. Due to the low-grade initial symptomatology, sleep-disordered breathing may be left untreated for a prolonged period with progressive worsening of symptoms over time.

Introduction

Sleep-disordered breathing (SDB) occurs when an anatomically small upper airway collapses during sleep. Children with an oral-facial anatomy leading to reduced upper airway size are at risk of developing SDB [1, 2]. Genes control facial structural development particularly during fetal life [3, 4]. Genetic mutations may lead to a syndromic presentation, but mutations may also lead to an isolated small maxilla and/or mandible [5] with secondary development of mouth breathing and obstructive sleep apnea (OSA) [1]. Environmental factors may also impact oral-facial development during childhood, as well demonstrated experimentally in the Rhesus monkey. Placement of a simple ligature on the nares reducing inspiratory nasal flow shortly after birth leads to a functional impairment related to increases in nasal inspiratory resistance [6–8]. This induced abnormal oral-facial muscle activity and oral-facial developmental changes in the absence of a genetic

✉ Christian Guilleminault
 cguil@STANFORD.EDU

1 Stanford University Sleep Medicine Division, Stanford Outpatient Medical Center, 450 Broadway Street, Pavilion B 2nd floor, MC 5730, Redwood City, CA 94063-5730, USA

2 Department of Orthodontics, University of California San Francisco Dental School, San Francisco, USA

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defect. Both genetic and environmental factors may result in small oral-facial structures, leading to a smaller upper airway and increasing the risk of upper airway collapsibility, particularly during sleep. There is an agreement that teeth, in the dento-alveolar region, play a role in the growth of the maxilla and the mandible at the level of the "alveolar zone" as mentioned by Moss and by Enlow [9–11]. This alveolar zone has been described as important in the vertical, sagittal, and transversal growth of the face. The dental development is involved in the development of this alveolar zone, and oligodontia has been associated with an absence of this alveolar zone, as defined by Moss [10, 11]. An abnormal absence of dentition is associated with the abnormal development of the lower part of the face. There is also an interaction between the upper and lower teeth and their position that plays a role in oral-facial development. This dynamic relationship between the alveolo-dental maxillary and mandibular region is outlined in textbooks of dentistry [12].

Ben-Bassat and Brin [13] studied children with missing teeth (with congenital agenesis in at least one third of their subjects) and found an abnormal oral-facial development in these children with concave profile, pointed chin, and reduced lower facial height, in association with their hypodontia. Others [14, 15] have also reported alteration in craniofacial morphology, particularly reduced maxillary and mandibular length, underdevelopment of the lower face, or prognathism in association with missing teeth. In these cases, the dental agenesis was either suspected to be related to genetic mutation or more rarely to environmental causes involving infection (e.g., rubella), chemotherapy, radiation, toxic substances (such as thalidomide), or extraction of temporary teeth. [16–20].

It is well demonstrated that abnormal oral-facial anatomy increases the risk of upper airway resistance and collapsibility during sleep. We thus questioned the impact of missing teeth early in life on the development of SDB. We looked for children with congenitally missing teeth who had been seen in an orthodontic practice and also at all children referred for "sleep disorders" who had had permanent teeth extraction early in life. We questioned if these children had findings of sleep-disordered breathing and if there was any similarity with the SDB noted in children with large adenotonsils. This retrospective investigation of data that was rendered anonymous was approved by IRB.

Methods

Search of the sleep medicine clinic database identified 31 children with known dental agenesis with a minimum of 2 missing teeth that were referred by the orthodontic practice during the 5 years covered by the search. These cases were confirmed by review of the orthodontic clinic database, and they included the total number of children with agenesis of at least two permanent teeth seen at the orthodontic office during the selected time. We considered two other children groups for comparison: 11 children without dental agenesis but who had early extraction of at least 2 permanent teeth (representing the total number of young children seen at the sleep clinic with mention in the chart of the dental extractions between 8 and 12 years of age) and 62 gender-, age- (±8 months), and BMI-matched (±0.5 kg/m^2) children with OSA related to enlarged adenotonsils (T&A) but with normal permanent dentition. The 62 children were selected based on the order of investigation at the sleep clinic. Each time that a child responded to the criteria of inclusion to serve as a control, this individual entered the research database. When 62 children had been identified in chronological order, no further search was performed.

Data extraction

For each subject, the following data were extracted: clinical history including clinical complaints, results of a pediatric questionnaire (Pediatric Sleep Questionnaire) [21], clinical evaluation, results of polysomnographic sleep study (PSG), follow-up information regarding treatment approaches, and follow-up results.

Data collection

At the sleep clinic, a standardized evaluation approach is followed by all practitioners. The nature of the sleep-related complaints and evolution over time is documented. Clinical evaluation follows a protocol established in the clinic to collect information systematically. Oral-facial anatomical findings were classified using previously used anatomic descriptive scales [22], including the Mallampati (score from 1 to 4) and Friedman tonsil (score from 0 to 4+) scales [23, 24]. In addition, further examination included assessment of the palate (hard palate height and width were assessed between the palatal shelves and the palate was described from wide and low to high and narrow), presence or absence of nasal septum deviation, investigation of inferior nasal turbinates, teeth number and position (cross bite, open bite, and abnormal position of upper and lower molars and canines), and determination of facial length and distribution per third of face (harmonic face) [22]. The length of the tongue frenulum and tongue movements were assessed through voluntary maneuvers, such as trying to touch the tip of the tongue to the nose and chin, curling and sticking out the tongue, and pushing the tip of the tongue against resistance. [25–27].

All PSG had been performed in a laboratory with continuous video monitoring. The following variables were systematically monitored in all cases: electroencephalography (four leads), eye movements (two leads), chin and leg electromyography and electrocardiography (one lead), and body movement (one sensor). Respiration was monitored with nasal

cannula pressure transducer; mouth thermocouple; chest and abdomen respiratory inductive plethysmography bands; intercostal/diaphragmatic, rectus, and oblique electromyograms; neck microphone for detection of noisy breathing; transcutaneous CO_2 electrode; and finger pulse oximetry from which oxygen saturation and finger plethysmography curve were derived on different channels. All data were collected on a Sandman™ (Ontario, Canada) sleep system. PSGs were scored following the recommendations of the 2007 American Academy of Sleep Medicine (AASM) [28] for sleep/wake stages and SDB; hypopneas and flow limitation were also scored following published criteria [29, 30].

Dental X-rays (in all cases), 3-D computed tomography (in dental agenetic children), and follow-up imaging studies performed at the orthodontic office were reviewed. The absence of permanent teeth was assessed on X-rays (Panorex X-rays), and this review was particularly important in young children to affirm agenesis. In the cases of congenital dental agenesis, genetic analysis in search of mutations was recommended to parents of all children, but testing was performed in only two children and their families by laboratories not affiliated with the institution (one Caucasian family in Belgium and one Far East Asian family in Taiwan).

Results

Subject referrals

The congenitally-missing-teeth children ($n = 31$, 5–15 years of age) came from one independent orthodontist office working in close collaboration with the sleep clinic. All children with congenital dental agenesis recognized by the orthodontist during the investigation period had been referred to the sleep clinic, despite at times significant resistance on the parents' part resulting in delays between recognition of agenesis and evaluation at the sleep clinic (up to 9 years in one case). The other children had been referred for suspicion of sleep-disordered breathing.

Permanent teeth missing

Per recruitment criteria, all children must have had at least two permanent teeth missing. There were 8 children with 2 missing teeth, 13 with 4, and 10 with more than 4 in the congenitally missing tooth group. There were five children with extraction of two incisors and six other children with four ($n = 5$) and six ($n = 1$) extracted teeth. The causes of extraction were related to "esthetic goal" and due to "teeth crowding." Headgear was used at night by 4 of the 11 children for 6 to 12 months to place the upper teeth in a more retrusive position. The "control" children with enlarged adenotonsils ($n = 62$, 4–15 years of age) were referred by pediatricians

for suspicion of OSA during the same time period and had a complete set of permanent teeth.

Complaints and symptoms (see Table 1)

All three groups of children showed overall normal general growth and development, normal BMI, and normal pediatric examination findings. Demographics, symptom list, and examination findings are presented in Table 1. The children from the dental extraction group were significantly older than the teeth agenesis children ($p = 0.0038$).

All studied children reported complaints and symptoms of OSA syndrome at sleep clinic evaluation (see Table 1). Sleepiness, fatigue, poor sleep, and impact on daily life (particularly school) were similar in the three pediatric groups. Inattention was more prevalent in the teeth agenesis and dental extraction groups, but was not significantly different from the T&A group. The prevalence of sleepwalking and sleep terrors was similar in the teeth agenesis group compared to the T&A group.

Table 1 also outlines the abnormal findings at oral-facial examination and dental imaging results. Mallampati scale scores were worse in the dental agenesis group while the Friedman tonsil scale scores were worse in the T&A group [23, 24] (see Table 1). At clinical evaluation, the children with missing teeth and clinical symptoms had not only abnormal Mallampati scores but all in this series also had a high and narrow palatal vault and presented with a long face. Measurement of the "harmonic face" (i.e., demonstration that the face is subdivided into three equal thirds, as reported) demonstrated in all the studied cases an abnormal subdivision with a longer lower third [22].

Voluntary tongue movements explored by maneuvers used by myofunctional therapists [25, 26] showed some reduction in performing maneuvers such as "touching the nose with tongue," "curling the tongue while protruding it," and "swallowing after placing the tip of your tongue behind the ridge just above your upper teeth" despite normal superior and inferior frenulum placement in the three children groups. There was also a common finding in nearly all the children: they manifest mouth breathing when attention was directed toward another task other than breathing evaluation.

Enlarged inferior nasal turbinates and allergic rhinitis were more frequently seen ($p = 0.001$) in the enlarged T&A children. Evaluation of palatal vault showed that all children with missing teeth (teeth agenesis and dental extractions) presented clearly with a high and narrow hard palate. Figures 1, 2, and 3 show examples of oral, facial, and radiologic findings in children with dental agenesis. All T&A children had had prior evaluation by otolaryngologists and had uneventful T&A surgery with follow-up PSG at 3 to 4 months post-surgery.

Table 1 Distributions of demographic variables and disease characteristics in SDB children

Variables	Tooth agenesis (n = 31)		Dental extraction (n = 11)		T&A (n = 62)		p value
	n	(%)	n	(%)	n	(%)	
Age in years, mean (SD)	10.17	(2.99)	13.45	(0.85)	10.18	(3.15)	0.015*
BMI (kg/m^2), mean (SD)	12.74	(1.85)	14.63	(1.00)	12.67	(1.87)	0.008*
Male	19	(61.3)	3	(27.2)	38	(61.3)	0.15
Sleepiness	7	(22.6)	4	(34.3)	18	(29.0)	0.65
Inattention	19	(61.3)	6	(64.5)	31	(50.0)	0.58
Fatigue	31	(100)	11	(100)	62	(100)	NS
Poor sleep	31	(100)	11	(100)	62	(100)	NS
Hyperactivity	9	(29.0)	1	(9.1)	14	(22.6)	0.70
Sleep walking	4	(12.9)	0	(0)	9	(14.5)	0.72
Sleep terrors	6	(19.4)	0	(0)	11	(17.7)	0.54
Headache	3	(9.7)	1	(9.1)	7	(11.3)	0.80
High palate	31	(100)	11	(100)			
Mallampati score							
2	0	(0)	0	(0)	6	(9.7)	<0.001**
3	9	(29)	3	(27.2)	51	(82.3)	
4	22	(71)	8	(72.7)	5	(8.1)	
Tonsil scale							
0	7	(22.6)	2	(19)	0	(0)	<0.001**
1	10	(32.3)	5	(45.4)	0	(0)	
2	25	(45.2)	4	(36.3)	3	(4.8)	
3	0	(0)	0	(0)	32	(51.6)	
4	0	(0)	0	(0)	27	(43.5)	
Deviated septum	4	(12.9)	3	(27.2)	18	(29.0)	0.25
Turbinate allergy	3	(9.7)	3	(27.2)	48	(77.4)	<0.001**
Wisdom	3	(9.7)	0	(0)	0	(0)	0.07
Bicuspids	13	(41.9)	4	(36.3)	0	(0)	<0.001**
Incisive	19	(61.3)	9	(82.0)	0	(0)	<0.001**

Due to selection criteria, there was no significant difference in either mean age or mean BMI between the children with dental agenesis compared to the T&A children, but children with dental extraction were significantly older than the tooth agenesis children (p = 0.004). Selection criteria for groups resulted in significant differences between the presence and absence of teeth. Deviated septum was scored on a "yes" or "no" scale. Turbinates were scored as "enlarged" when the inferior turbinates occupied at least 50 % of the intranasal space

BMI body mass index, SD standard deviation, Mallampati-Friedman modification scale (with scores from 1 to 4) and other anatomic visual scores were performed following criteria previously used in studies of SDB children by Kim and Guilleminault [22]

Statistics was performed using Fisher's exact test and Kruskal-Wallis H test: * significant p values <0.05; **p < 0.001

Polysomnography results

PSG results (see Table 2) demonstrated abnormal findings in all subjects: apnea-hypopnea indices (AHI) were elevated, and flow limitation and mouth breathing were present in excessive amounts [29–32]. Obstructive hypopneas were associated more with EEG arousals than with oxygen saturation (SaO$_2$) drops of at least 3 %, but the lowest observed oxygen saturations were always abnormal in the three children groups, oscillating between 91 and 88 %. All subjects were mouth breathers for more than 50 % of the monitored time on PSG including in the dental groups (mean 62 ± 7 % in dental

agenesis group and 66 ± 10.3 % in the dental extraction group) [31, 32].

Table 2 compares AHI, flow limitation, and baseline SaO$_2$ between pediatric subjects with teeth agenesis, dental extraction, and T&A. We included flow limitation as a parameter for comparison because the presence of flow limitation has been linked to clinical complaints in children and young adults [29, 30, 33].

Non-parametric Kruskal-Wallis H test demonstrated a significant difference among the 3 pediatric groups for AHI (p < 0.001) (see Table 2), and Dunn-Bonferroni post hoc test showed AHI is significantly lower in the teeth agenesis group
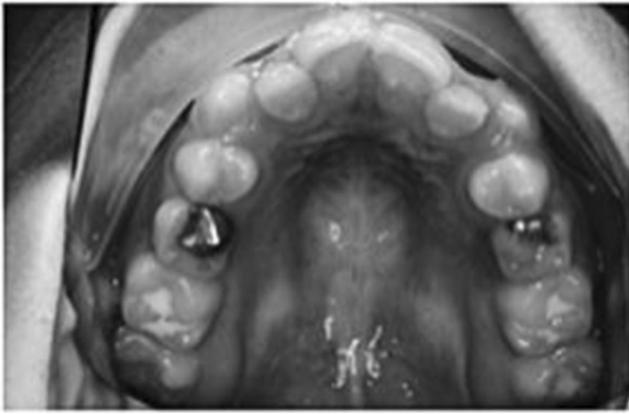
Fig. 1 Oral examination findings in a child with dental agenesis (two missing incisors): Note the presence of a high and narrow hard palate in a 7-year-old child as observed frequently in OSA children

compared to either the dental extraction or the T&A groups. Among the three pediatric groups, there is no significant difference when comparing percent of time spent with flow limitation during the entire sleep time or when comparing SaO_2 nadir. Flow limitation was more prevalent in younger subjects, and AHI was more elevated in older individuals. Our data are cross-sectional, but we ranked subjects with missing teeth by age and looked at AHI. Figure 4 demonstrates the significant correlation between AHI and age in these children with a significant regression coefficient ($R^2 = 0.71$, $p < 0.0001$). The post-surgery T&A patients had at follow-up PSG and

Fig. 2 Profile presentation of a 10-year-old child patient with abnormal oral-facial growth associated with congenital dental agenesis (two missing incisors). Note the retroposition of the mandible and abnormal facial growth

AHI of 1.3 ± 1, with 11 subjects with an AHI between 1.5 and 2 and 3 subjects with an AHI between 2 and 3 events/h.

Family history

In the teeth agenesis group, the family histories of dental problems were poorly documented except in three cases: dental agenesis of third molars (wisdom teeth) was reported in son (index case), mother, and maternal grandmother; in daughter (index case) and father; and in son (index case) and mother. In these three families, the identified parents were diagnosed (including PSG) and treated for OSA in three of the four identified adults. Despite the positive family history, no genetic analysis was available in these cases.

Finally, in one dental agenesis case, there was documentation of long orthodontic follow-up from early childhood (3 years of age) until acceptance of sleep evaluation (12 years of age) due to clinical symptoms. In this case without enlargement of tonsils and adenoids, there is imaging documentation of a progressive worsening of the palatal vault width and maxillary deficiency with correlated worsening of the oral evaluation. Two families independently underwent testing by foreign laboratories and had documentation of a genetic mutation that has been previously related to dental agenesis.

Discussion

Our results show that SDB should be a significant concern in young children with missing teeth and questions about missing teeth in the family and congenitally missing teeth should be asked when evaluating a child with suspicion of OSA.

Several important findings and points must be emphasized:

1. All observed children were non-overweight.
2. None of the children with congenital dental agenesis were referred initially to a sleep clinic, and parents were often unconvinced initially of the necessity of having a sleep evaluation when the dental agenesis was recognized. This often led to delayed sleep clinic consultation and PSG until the appearance or recognition of sleep-related symptoms. The symptomatology related to the SDB became more pronounced over time.
3. Our study confirms the prior results of Ben-Bassat and Brin [13]. Independently of the reason behind the teeth agenesis or absence, children missing at least two teeth had an abnormal oral-facial presentation when seen in the sleep clinic. This included a long and narrow face, narrow and high palatal vault, abnormal length of the lower one third of the face (disharmonic face [22]), and abnormal clockwise rotation of the mandible. These findings have previously been described in children with a narrow upper

Fig. 3 X-rays of a 5-year-old child with missing teeth 20 and 29 (permanent lower second bicuspids): dental agenesis can be recognized with a Panorex X-ray, a dental X-ray that provides a panoramic view of the entire upper and lower dental arches and the temporomandibular joint. This is a radiologic procedure that is commonly performed in pediatric and adult dental practices. The missing teeth are marked with an *arrow*, showing the agenesis with the overlying primary teeth still in place

airway and are known risk factors for increased upper airway collapse during sleep. [1].

The dento-alveolar region plays a role post-natally on the growth and development of the face, and its interaction with the oral-facial muscles is important in such development. This relationship is present for both the maxilla and mandible. Missing permanent teeth have been reported to lead to transverse maxillary deficiency with decreased distance between the lateral walls of the nasal cavity and the nasal septum, reduced size of the nasal cavity, and increased resistance to nasal airflow [34–37], but the mandible will also be affected. There is a continuous interaction between growth of the oral-facial region and the size and secondary collapsibility risk during sleep of the upper airway. Impairment of normal oral-facial development may vary depending on the number of missing teeth, the age of the subject, and the impact of the changes on the facial muscles. These changes may gradually impact the width and stability of the upper airway during sleep and symptoms may be noted by parents after a variable time interval. The clinical history obtained from subjects and their family supports this concept. In the dental agenetic group, teeth were absent at birth but symptoms were noted well after birth, becoming more evident with time and PSG studies demonstrating increasing AHI with aging. As

mentioned, the most extreme case in our series was recognized with congenitally missing two upper lateral incisors at 3 years of age, but parents refused to pursue any treatment. As the child was followed in the same dental practice, over time, clinical information and subsequent X-rays were available. There were concerns expressed to the parents by the specialist related to changes observed in facial presentation with development of a clockwise rotation of the mandible and the appearance of a narrow and high palatal vault. As the parents did not observe symptoms, they rejected any further investigation. But 2 years later when clinical symptoms were noted, the clinical evaluation indicated more important palatal narrowing and there was an abnormal AHI at polysomnography.

There is a continuous interaction between the different components of the oral cavity during development. These anatomic components also interact with different functions: suction, mastication, swallowing, phonation, and mouth breathing. These various components are also part of the maintenance of a normal airway size during sleep. Impairment of one element has an impact on others, and if no compensation for the defect occurs, there are progressive changes that impact other elements of the oral cavity and lead to the appearance of symptoms when other changes are present. The initial defect may be present very early but its consequences may be seen much later.

Table 2 Comparisons of AHI, flow limitation, and SaO_2 among children with teeth agenesis, dental extraction, and T&A

	Tooth agenesis ($n = 31$)		Dental extraction ($n = 11$)		T&A ($n = 62$)		p value	Post hoc test
AHI	7.32	(2.03)	9.00	(1.31)	12.26	(3.14)	<0.001	1 < 2; 1 < 3; 2 < 3
Flow limitation	74.39	(8.58)	71.88	(5.94)	73.87	(6.74)	0.73	
SaO_2	90.23	(1.15)	90.25	(0.71)	90.13	(0.14)	0.97	

1 tooth agenesis, *2* dental extraction, *3* T&A (in the post hoc test)
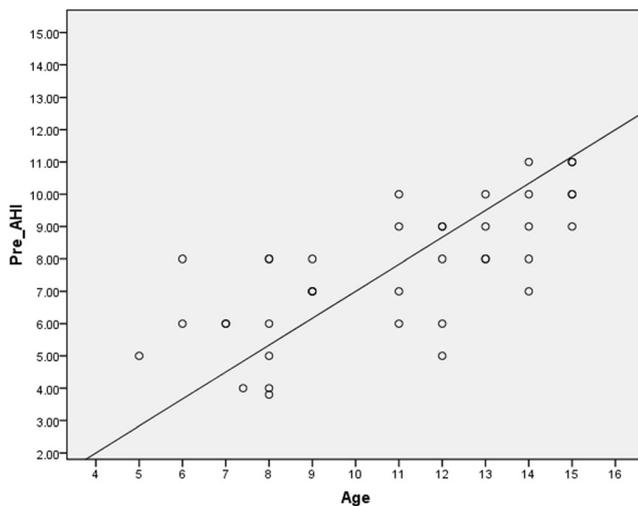
Fig. 4 Correlation between age and Apnea-Hypopnea Index (AHI) before any treatment in children with agenesis and teeth extraction (n = 43). A progressive increase in AHI with age is shown with a significant positive correlation ($R^2 = 0.71$, $p < 0.0001$) (linear regression). Several children are superimposed in the segment from 13 to 15 years of age

Congenitally missing teeth may be associated with syndromes, but it is often seen in isolation. Its estimated prevalence varies by study, but most report it affecting between 10 and 20 % of the studied population [38]. Most commonly, only one tooth is agenetic, but in 10 % of the agenetic cases, two teeth are absent with the second premolar and the lateral incisor more frequently involved in agenesis and 1 to 2 % have oligodontia [38, 39]. As described in the protocol, we only considered children with at least two missing teeth. Congenitally missing teeth may be related to different causes and may be due to a mutation that may run in families. The family history of dental anomalies was overall poorly documented in our subjects. Two children with oligodontia were part of families that had been studied by others. One Caucasian child had a missense mutation in the Ectodysplasin A (EDA) gene and a Chinese child had a missense mutation involving the WTA 10 gene. None of the other children had genetic evaluation.

Clinically, it is important to integrate missing teeth (their location and number) in the investigation of children with SDB. Moreover, it is important for dental specialists to recognize the potential risk of developing OSA with missing teeth and to use treatment approaches avoiding permanent teeth extractions.

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