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ORIGINAL ARTICLE

A case–control study of craniofacial features of children with obstructed sleep apnea

Jinrong Deng · Xuemei Gao

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Abstract
Objective This study aims to analyze differences in the skeletal, dental, and soft tissue components of craniofacial structure predisposing to the pediatric obstructive sleep apnea, by a comparison of the cephalograms between children with obstructive sleep apnea (OSA) and controls.
Materials and methods The study enrolled a total of 30 children who were composed of the following two groups: 15 OSA patients and 15 controls. The two groups were strictly matched by age and sex. Lateral head radiographs were obtained and then cephalometric measurements were compared between the two. Fifty-six measurements were determined to study various skeletal, soft tissue, and airway structure.
Results Marked differences were demonstrated in terms of SNB, PG-NB, lower facial height, H-C3Me, and adenoid (*A*) and tonsil (*T*/*P*). The SNB angle (75.82±4.30) in case group was smaller than in the control (78.71±2.61; $p=0.035$), the PG/NB value in case group (1.32±0.84 mm) was higher than that in the control (0.62±0.60 mm; $p=0.015$). The anterior lower facial height was 65.12±5.91 mm in case group ($p=0.048$), while the anterior lower facial height in control was 61.51±3.22 mm. The position of hyoid was lower in case group (5.30±3.67 mm) compared with the control one (2.64±2.58 mm; $p=0.029$). Furthermore, the patients with OSA had larger *A*s and *T*/*P*s than the controls.
Conclusions The case group differed from the control group in the length of mandible, anterior lower facial height, position of hyoid and the chin, and the size of the *A*s and *T*/*P*s.

Keywords Pediatric sleep apnea syndrome · Craniofacial features · PSG · Cephalometrics

J. Deng
3rd dental centre, School and Hospital of Stomatology, Peking University, Beijing, China

X. Gao (✉)
Department of Orthodontics, School and Hospital of Stomatology, Peking University,
22 Zhongguancun NandajieHaidian District Beijing 100181, China
e-mail: xmgao@263.net

Introduction

Obstructive sleep apnea (OSA) is a breathing disorder characterized by repeated episodes of prolonged upper airway obstruction and/or intermittent complete obstruction that disrupts normal sleep patterns (American Thoracic Society [1]). It is not a common problem in childhood with the prevalence of 0.8~2% [2], which, if left untreated, can result in severe complications, e.g., failure to thrive, cor pulmonale, neurocognitive deficits, and mental retardation. Early recognition of such children is getting worldwide attention which will lead to less prevalent complications [3].

The craniofacial features of OSA children have always been an area of interest in orthodontics. Topics such as the relationship between facial type and airway anatomy, respiratory function and abnormalities of maxilla and mandible were explored [4, 5]. It was fundamental to evaluate craniofacial characteristics in sleep apnea patients by cephalometric radiographs. This procedure was commonly carried out on adult OSA patients [6], while children suffered from OSASH were less involved in studies of the same sort [7].

All the concerned subjects in this study were strictly matched by sex and age and underwent a nocturnal polysomnography (PSG)—the golden standard of a sleep apnea situation confirmation.

The purpose of this project was to compare the craniofacial features of children with and without sleep apnea using cephalometric analysis.

Methods

Subjects

A total of 15 patients with sleep apnea were transferred from sleep centers of Beijing Children's Hospital. The case group with a documented sleep apnea was composed of 4 girls and 11 boys aged from 6 to 12 years old. The mean age was 9.5 ±1.0 years old. The mean AHI observed in case group was 6.29±6.48 incidents/h.

The controls were recruited from 2,658 first visit patients in Department of Orthodontics, School and Hospital of Stomatology, Peking University. All patients were local Chinese residents receiving questionnaire survey and clinical review. Children who snored or had congenital diseases were excluded from the study. Out of 550 eligible children, 40 aged from 6 to 12 were chosen in the cephalometry with the approval of medical ethical council in Peking University. The study flow chart was shown in Fig. 1.

The polysomnography was performed in the overnight sleep laboratory in Beijing Children's Hospital. Each record was scored by a sleep disorder technician, with the results interpreted by certified clinical polysomnographers. The evaluation consisted of a number of parameters including electroencephalogram, electrooculogram, electromyogram, electrocardiogram, recordings of nasal and oral airflow, oxygen saturation, thoracic movements, and muscle activity. Apnea Hyponea Index (AHI) [8] was used to assess the severity of sleep apnea and represented the parameter to separate the two groups defined on the basis of the apnea plus hypopnea frequency. AHI>1 incident/hour was assumed abnormal in children patients [1]. Body mass index adjusting body weight for individual weight differences in stature (in kg/m^2) was also determined for each subject.

All the chosen 40 patients underwent PSG, and 25 children were believed to have normal sleep according to the sleep report. Out of the 25 children, 15 children were selected to take part in the study according to age and sex of the case group. Four girls and 11 boys aged from 8 to 11 years were enrolled, with the mean age of 9.6±1.8 years. The mean AHI in control group was less than 1 incident/h.

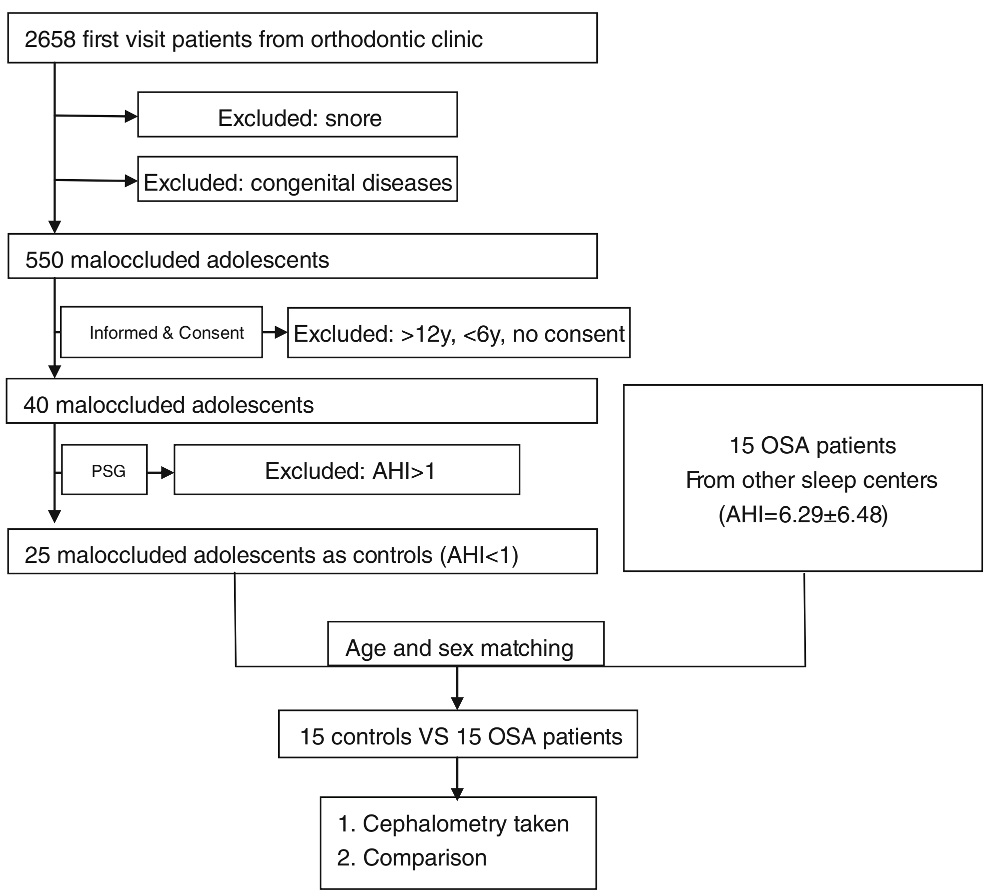

Fig 1 The study flow chart (*PSG* polysomnography, *OSA* obstructive sleep apnea)

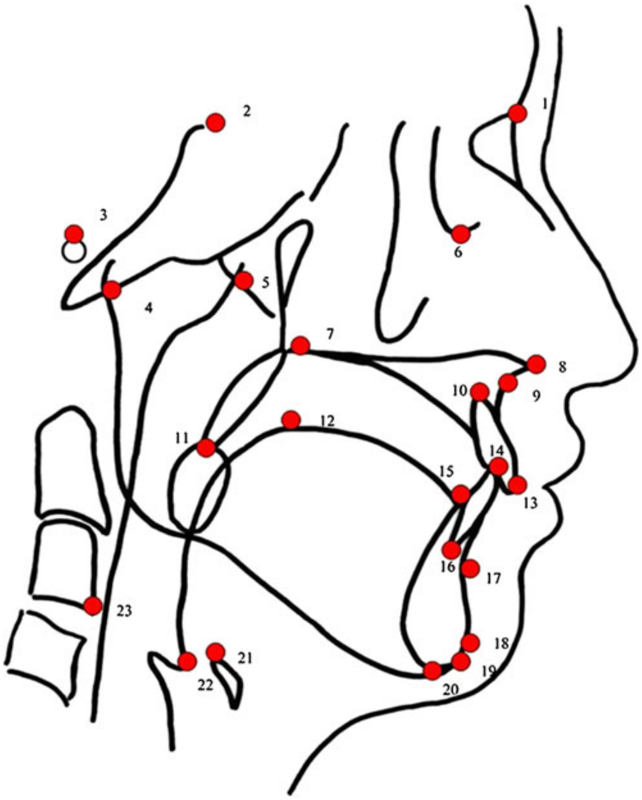

Fig. 2 Reference points: *1* nasion, *2* sella, *3* porion, *4* articulare, *5* roof of upper airway, *6* orbitale, *7* PNS posterior nasal spine, *8* ANS anterior nasal spine, *9 A* point, *10* root apex of upper incisor, *11* P tip of soft palate, *12* roof of tongue,*13* edge of upper incisor, *14* edge of lower incisor, *15* tip of tongue, *16* root apex of lower incisor, *17* point *B*, *18* pogonion, *19* gonion, *20* menton, *21* hyoid point, *22* base of epiglottis, *23* lower anterior point of C2

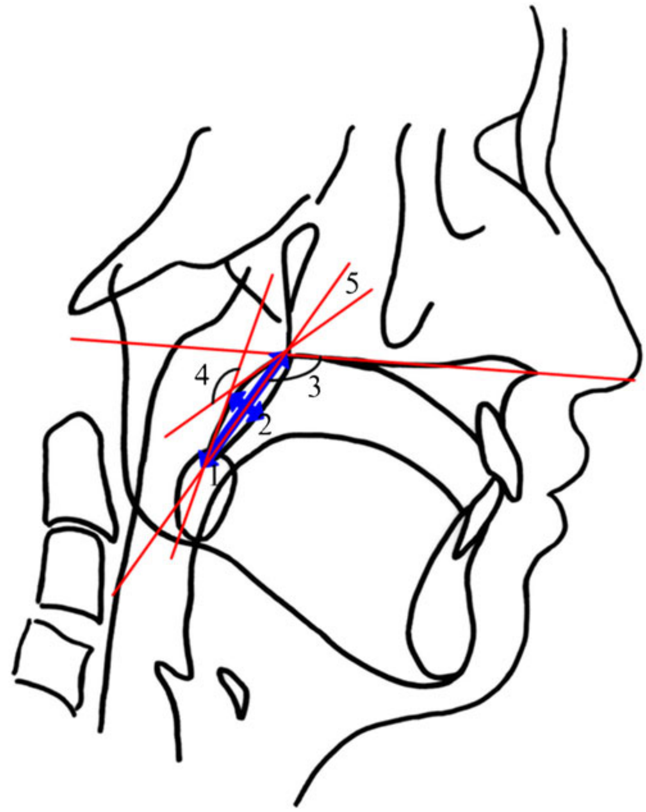

Fig. 3 The soft palate measurements: *1* length of soft palate (*SPL*), *2* thickness of soft palate (*SPT*), *3* angle of soft palate, *4* inclination of soft palate, *5* area of soft palate

Data were calculated and used with consent obtained after explaining the purpose and contents of the study to the patients and their parents.

Cephalometric analysis

The same Orthophos X-ray apparatus OC-100 (Instrumentarium Imaging Company, Finland) was used to obtain the lateral cephalograms in a standardized fashion with a fixed cathode-to-head distance of 150 cm. The subject was in upright natural standing head position with the gaze parallel to the floor. All cephalograms were taken at the end of inspiration after the subject was instructed not to speak and swallow.

The cephalogram was traced manually on the 0.03 inch thick acetate paper by one of the investigators and checked by another. To determine the observer error, ten radiographs were randomly selected 2 weeks later and re-traced by the same investigator. If there was marked difference between the two measurements, this procedure was repeated for the third time. The mean value of the closest two observed readings were adopted. The error for linear and angular measurements of cephalometric analysis was measured using the Dahlberg's formula $E = \sqrt{\sum d^2/2n}$. The linear measurement error was averaged to be 0.5 mm and 0.5° for angular measurement. It should be pointed out that a magnification of the linear parameters was produced during the cephalometry taking process. A scale on the cephalometry was used to correct the magnification by division of the original length and the length magnified on the cephalometry.

The cephalometric analysis was based on 56 measurements: 22 angular measurements, 26 linear measurements, 2 area measurements, and 6 ratio measurements [9].

Figure 2 shows the cephalometric reference points used for all measurements. Figure 3 shows the measurements of soft palate, including the length, thickness, angulation and area of the soft palate. Figure 4 shows data of the tongue measurements which consisted of length, height, thickness and area of the tongue. Three parameters were demanded to evaluate the hyoid position, which are shown in Fig. 5. Figure 6 illustrates measurements in four locations along the upper airway. The width of the nasopharyngeal airway space was measured from the anterior wall of prevertebral soft tissue and posterior wall of soft palate along the

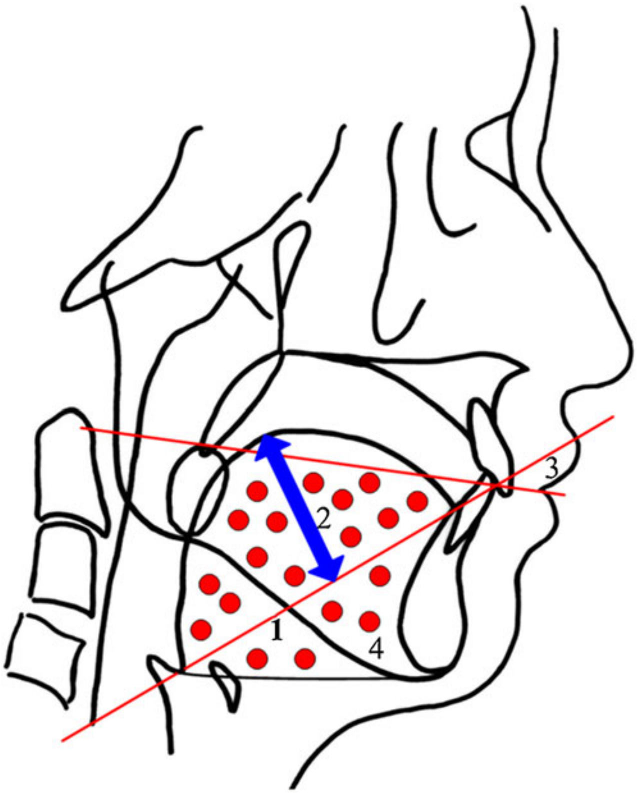

Fig. 4 The tongue measurements: *1* length of tongue, *2* thickness of tongue, *3* inclination of tongue, *4* area of tongue

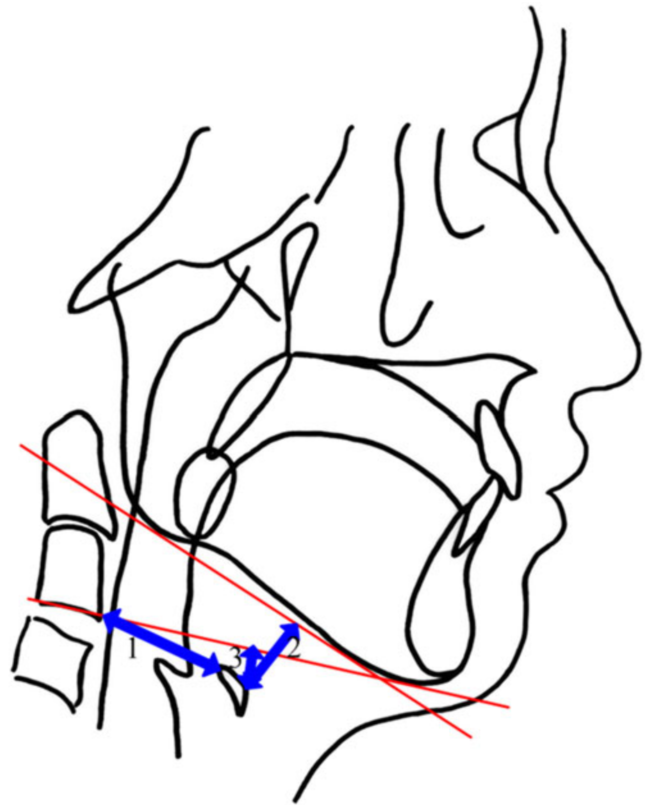

Fig. 5 The hyoid measurements: *1* the distance of C3 and hyoid, *2* the distance of hyoid to mandibular plane (*H-MP*), 3, the distance of hyoid to the line connecting C3 and Me (*H-C3Me*)

extension of the palatal plane, as defined by the line connecting anterior nasal spine and posterior nasal spine (number 1). Number 2 represented velopharyngeal space which was measured from along a line extending from the occlusal plane. Another measurement was made for the oropharyngeal space along mandibular plane (number 3). We also evaluated the PAS which represented glossopharyngeal space extending from a plane along point B and gonion (number 4), and the vertical dimension of the airway which connected epiglottis and posterior nasal spine (number 5). Figure 7 is a schematic image of parameters of adenoid (*A*) and tonsil (*T*/*P*).

Statistical analysis

Statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS) software for Windows (version 11.0; SPSS Inc, Chicago, Ill). Data in the two groups were presented as mean and standard deviations (in Table 1). Given the data fit a normal distribution and homogeneity of variances, the inter-group differences were tested with paired *t* tests. Statistical significance was tested at $p<0.05$, $p<0.01$, and $p<0.001$. $p<0.05$ was considered significant in general. Bonferroni correction was used to adjust for multiple testing in this study, comparison should be done at a significance level of α/n. So, we will compare the means of the two paired groups at the level of 0.05/56 (0.000892) in this study.

Power calculations

Post-hoc statistical power for each *t* test was achieved by Power Analysis and Sample Size Software for Windows (version 2008; NCSS Inc, Utah, USA). Only comparison with a power over 80% was considered to have statistically significant differences. Power calculations were based on comparison results with $n=15$ OSA cases and $n=15$ controls.

Results

Dental maxillofacial measurements in two groups

Dental maxillofacial structure including maxilla, mandible, and dental spatial and functional position has deep connection with ventilation function. The results of dental maxillofacial measurements taken were summarized in Table 1. Three parameters revealed a significant difference between

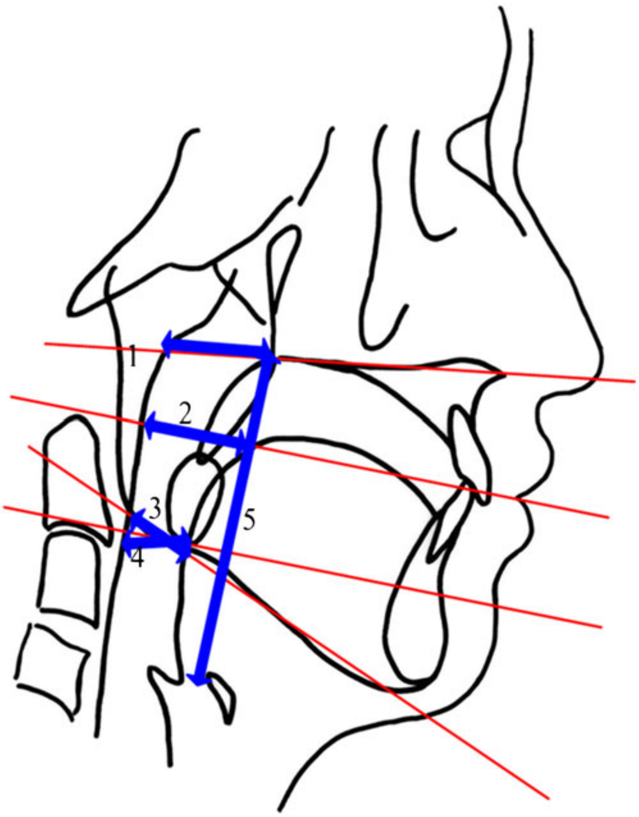

Fig. 6 The airway measurements: *1* width of upper airway, *2* width of middle airway, *3* width of lower airway, *4* PAS, *5* vertical dimension

the mean values of the two groups: SNB (78.71±2.61 vs. 75.82±4.30), PG-NB (0.62±0.60 mm vs. 1.32±0.84), Na-Me (108.50±6.93 mm vs. 13.62±10.0 mm), and ANS-Me (61.51±3.22 mm vs. 65.12±5.91 mm), with the statistical power listed in the corresponding form. All the listed powers are not very high, but there is a tendency that the case group has retrusive mandible and chin, and longer face.

Airway-related measurements in the two groups

The pathogenesis of pediatric OSA remains unclear, but the anatomic factor reached a worldwide consensus [10]. Researchers believed that airway was closely related with soft tissue, tongue, hyoid, and other tissue surrounded. That is why the comparisons of the surrounding tissue were made. The results of the independent *t* test of the airway, soft palate, tongue are listed in Tables 2, 3, and 4, respectively. But surprisingly, a significant difference between the two groups was absent in these measurements.

The comparative results of hyoid position in two groups are displayed on Table 5, although the difference is not statistically significant, the power of lower hyoid position was also not quite high according to the post hoc power analysis, there is an indication of more inferior and retrusive hyoid in case group.

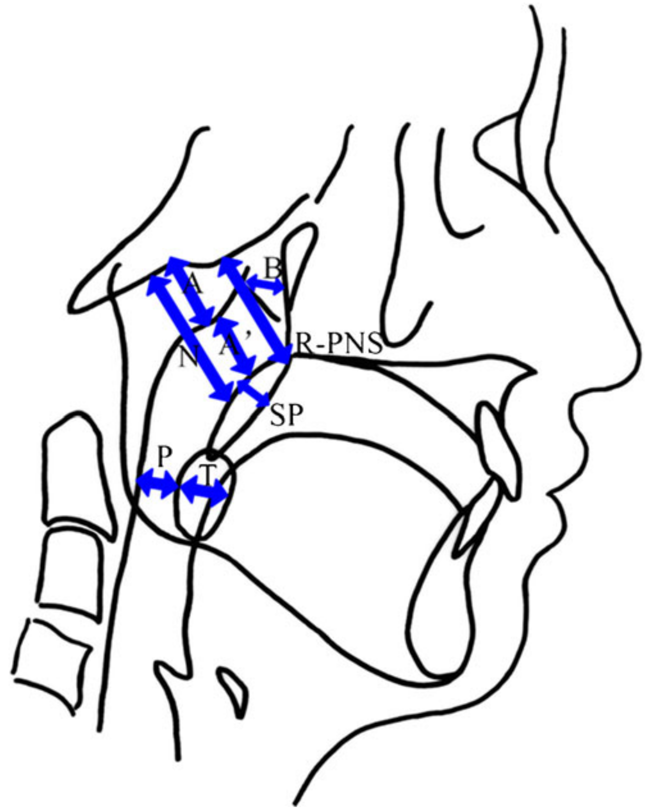

Fig. 7 The adenoid and tonsil measurements: *A* width measured at the most protrusive place of adenoid, *B* width of choana, *N* width of skeletal upper airway, *A′* width of airway at the most protrusive place of adenoid, *SP* width of soft palate at the most protrusive place of adenoid, *R-PNS* a line connecting PNS and roof of pharynx, *T* radius of tonsil, *P* width of airway at the most protrusive place of tonsil

The method evaluating the dimensions of *A* and *T*/*P* was also explored in this study, and powers of these parameters were also provided. The results on Table 6 suggested that *A* and *T*/*P* were two parameters with significant difference, but after Bonferroni correction and power analysis only *T*/*P* has high sensitivity with a power (98.8%) higher than 80%.

Discussion

Craniofacial anatomic factors, together with the mechanism of upper airway compliance and muscle function were said to play an important role in OSAHS [11, 12]. Cephalometric radiographs were commonly recommended to characterize the craniofacial hard and soft tissue structures of patients with and without OSAHS. The existing cephalometric comparison studies mainly focused on adults [6, 13, 14], which were unpopular in Asian children population. The research on children had seldom been shed light on due to lack of normal values and unavailable sample.

The results of the study showed that only 9 out of 56 measurements differed significantly between the two groups

Table 1 The comparison of dental maxillofacial measurements between OSA children and controls

Measurements	Controls	Patients	*P* value vs. 0.05 (power)	*P* value vs. 0.000892
SNA (°)	82.29±2.90	80.26±5.20	0.199	0.199
SNB (°)	78.71±2.61	75.82±4.30	0.035* (57.0%)	0.035
ANB (°)	3.58±2.39	4.43±3.10	0.403	0.403
FN-NP (°)	83.24±4.36	82.29±3.43	0.517	0.517
NA-AP (°)	7.62±5.70	8.82±8.51	0.651	0.651
U1/NA (°)	3.97±2.65	4.26±2.04	0.733	0.733
L1/NB (°)	5.43±1.97	6.39±2.69	0.278	0.278
U1-L1 (°)	125.11±15.1	121.48±9.93	0.444	0.444
U1-SN (°)	106.53±10.9	105.96±7.91	0.872	0.872
MP/SN (°)	38.84±4.21	41.31±6.08	0.207	0.207
MP/FH (°)	34.46±6.56	34.91±5.28	0.838	0.838
L1-MP (°)	89.51±6.61	91.23±6.12	0.465	0.465
Y (°)	67.02±6.08	67.18±3.83	0.931	0.931
Pg-NB	0.63±0.61	1.37±0.89	0.027* (72.5%)	0.027
PP-FH (°)	4.67±3.52	2.86±2.62	0.023* (33.8%)	0.023
OP-FH (°)	17.93±4.76	16.80±4.47	0.507	0.507
NSBa (°)	119.93±27.5	131.20±4.83	0.129	0.129
RP-FH (°)	85.50±6.42	82.93±3.79	0.193	0.193
Cranio-cervical Angle (°)	107.80±11.6	110.46±8.56	0.480	0.480
Ar-GoGn (°)	129.36±5.11	131.10±6.08	0.406	0.406
U1-NA (mm)	23.99±11.64	24.77±6.67	0.824	0.824
L1-NB (mm)	26.79±6.75	27.49±7.02	0.782	0.782
PG-NB (mm)	0.62±0.60	1.32±0.84	0.015* (71.6%)	0.015
SN (mm)	57.94±2.56	60.81±7.71	0.182	0.182
SBa (mm)	43.08±3.17	43.51±5.19	0.786	0.786
Nme (mm)	108.50±6.93	113.62±10.0	0.044* (34.9%)	0.044
NaAN (mm)	47.60±6.13	50.61±4.63	0.14	0.144
ANS-Me (mm)	62.17±3.08	67.43±6.35	0.014* (78.6%)	0.014
ArGo (mm)	39.05±2.48	40.90±4.12	0.151	0.151
SGo (mm)	68.07±4.45	69.99±6.58	0.356	0.356
ANSPNS (mm)	40.60±3.84	41.31±5.90	0.699	0.699
GOGN (mm)	62.86±3.99	63.51±8.53	0.791	0.791
S-Ar (mm)	34.50±3.19	32.91±4.17	0.253	0.253

SNA angle of a line connecting nasion and A point and SN plane, *SNB* angle of a line connecting nasion and B point and SN plane, *ANB* subtraction of SNA and SNB, *FH-NP* the angle of facial plane(NP) and Frankfort plane, *NA-AP* the angle of NA and AP, *U1/NA (°)* the angle of long axis of upper incisor and NA plane, *L1/NB (°)* the angle of long axis of lower incisor and NB plane, *U1-L1 (°)* the angle of long axis of upper and lower incisors, *U1-SN (°)* the angle of long axis of upper incisor and SN plane, *MP/SN (°)* the angle of mandibular plane and SN plane, *MP/FH (°)* the angle of mandibular plane and Frankfort plane, *L1-MP (°)* the angle of long axis of lower incisor and mandibular plane, *Y (°)* the angle of a line connecting sella and gnion and Frankfort plane, *PP-FH (°)* the angle of palatal plane and Frankfort plane, *OP-FH (°)* the angle of occlusal plane and Frankfort plane, *NSBa (°)* the angle of a line connecting nasion and sella and SN plane, *RP-FH (°)* the angle of ramus plane and Frankfort plane, *craniocervical angle (°)* the angle of posterior tangential line of C2 and SN plane, *Ar-GoGn (°)* the angle of a line connecting articulare and gnion and GOGN plane, *U1-NA (mm)* the distance of incisor edge of upper incisor to NA plane, *L1-NB (mm)* the distance of incisor edge of lower incisor to NB plane, *PG-NB (mm)* the distance of pogonion to NB plane, *SN (mm)* the distance of S and nasion, *SBa (mm)* the distance of S and basion, *Nme (mm), anterior facial height* the distance of nasion and menton, *NaANS (mm)* the distance of nasion and ANS (upper anterior facial height), *ANSMe (mm)* the distance of ANS and Me (the lower anterior facial height), *ArGo (mm)* the distance of articulare and gnion, *SGo (mm)* the distance of S and gnion, *ANSPNS (mm)* the distance of ANS and PNS, *GOGN (mm)* the distance of gonion and gnathion, *SAr (mm)* the distance of sella and articulare

*$P<0.05/32=0.000892$ vs. controls

when compared at the level of $p=0.05$, but after adjustment by Bonferroni correction, there is only one parameter differed significantly(power=98.8%). The results did not exactly mean that the two groups are only different in

Table 2 The comparison of airway measurements between OSA children and controls

Airway measurements	Controls	Patients	P value
Nasopharyngeal Space (mm)	16.56±3.60	16.56±5.85	0.999
Velopharyngeal Space (mm)	9.30±2.16	8.72±3.19	0.561
Oropharyngeal Space (mm)	10.23±2.70	9.36±4.26	0.512
PAS (mm)	6.73±2.01	5.54±2.58	0.172
Vertical dimension (mm)	56.53±5.49	60.98±12.80	0.227

dimensions of tonsil. On the contrary, not only the significant different measurements between the two groups can we find from the results but also can we discover some tendencies which were covered by the statistical results which would be discussed below.

The skeletal and dental measurements showed that the SNB angle of patients was smaller than the controls indicating that the mandible was possibly retrusive, which was identified with previous findings. A study of 28 snoring and 28 non-snoring children at the age ranging from 7 to 14 years was presented by Hans [15] in 2000. He concluded that the snoring children had craniofacial features of more retrusive maxilla and mandible compared with the normals. Baik and Ozdemir [16, 17] also reported that the snoring children had deficient mandible. This posterior position of the mandible relative to the maxilla may contribute to the narrowing of the oropharyngeal and hypopharyngeal space, as well as the susceptibility to development of OSA.

At the same time, patients with sleep apnea showed an increase tendency in PG-NB (1.32±0.84 mm) compared with the control group (0.62±0.60 mm), which indicated that the OSA children may had deficient chin. It was consistent with the results of previous research. According to Ozdemir's study [17], children with sleep apnea had small mandible and chin. The main reason is that the airway obstruction interferes with their craniofacial development. Another issue to be addressed here is that small mandible and chin also have an impact on the airway function.

Another indispensable element in children with sleep apnea is the position of hyoid. H point is the lower and anterior point of the hyoid which usual refer to the position of hyoid. According to the H point, three parameters, the vertical distance of hyoid to mandible (H-MP), the sagittal distance to the third cervical vertebra (C3-H), and the vertical distance to C3-Me plane (H-C3Me) [18], were adopted in this study. The results in Table 5 revealed a significant difference in one of the three measurements—H-C3Me at the level of $p=0.05$ but not significant different at the level of corrected p value. The result suggested that children with sleep apnea may have lower hyoid, but not confirmed in this study. This finding was partially in agreement with other studies, e.g., the research of Behlfelt and Linder-Aronson [19] supported that the children with sleep apnea had more inferiorly positioned hyoid. Another research of children with sleep apnea and cephalometric analysis was carried out by Kawashima [20] in Japan, and he concluded that lower hyoid was always presented in sleep disordered breathing children in his study and recommended cephalometric analysis as a valuable tool for conducting presurgical evaluation of sleep apnea in children of school age. The position of the hyoid bone served as a central anchorage for the tongue muscles and determined the position of the tongue. A lower hyoid bone might be a compensatory mechanism to alleviate the increased airway resistance caused by a reduced airway space, or it might be the result of a greater tongue mass. A downward and forward position of the hyoid was noted in children with enlarged *T*/*P*s and *A* [19].

The phenomenon of lower position of hyoid in children with sleep apnea is thought provoking. As we know, adults with sleep apnea are characterized by lower hyoid, so the change of a child's hyoid position during growth becomes a puzzle. Is it continuity for an OSA patient to have a lower hyoid? Or the position of hyoid will descend with time as a

Table 3 The comparison of soft palate measurements between OSA children and controls

Soft palate measurements	Controls	Patients	P value
Length (mm)	32.71±3.43	33.28±6.07	0.753
Thickness (mm)	6.32±1.26	6.88±1.70	0.322
Angulation (°)	136.83±6.55	137.46±7.54	0.808
Shape (°)	134.93±7.93	133.80±9.08	0.719
Area (mm^2)	269.26±64.70	269.73±550.87	0.987

Table 4 The comparison of tongue measurements between OSA children and controls

Tongue measurements	Controls	Patients	P value
Length (mm)	57.26±6.28	62.05±9.39	0.111
Thickness (mm)	45.81±4.84	42.82±10.81	0.337
Inclination (mm)	36.90±6.54	35.73±8.82	0.684
Area (mm^2)	1,968.08±367.91	1,962.17±550.86	0.973

Table 5 The comparison of hyoid measurements in OSA children and controls

Hyoid measurements	Controls	Patients	P value vs. 0.05 (power)	P value vs. 0.000892
C3H	25.93±4.26	27.71±3.58	0.226	0.226
HMP	9.52±4.82	10.88±7.27	0.552	0.552
H-C3Me	2.64±2.58	5.30±3.67	0.029* (60.0%)	0.029

*$P<0.05$ vs. controls

Table 6 The comparison of adenoid and tonsil measurements in OSA children and controls

A&T measurements	Controls	Patients	*P* value vs. 0.05 (power)	*P* value vs. 0.000892 (power)
A (mm)	1.60±0.63	2.20±0.68	0.045* (67.9%)	0.045
A/*N*	0.59±0.15	0.62±0.21	0.680	0.680
A/*B*	1.62±0.63	2.15±1.09	0.127	0.127
A′/SP	1.03±0.49	0.98±0.56	0.814	0.814
T (°)	1.07±0.26	1.33±0.49	0.072	0.072
T/*P*	0.85±0.29	1.38±0.37	0.000* (98.8%)	0.000* (98.8%)

*$P<0.05$ vs. controls

result of gravity? Of course, all the answers need a further exploration.

The results of this study had also demonstrated a significant increase in dimensions of *A* and *T*/*P* at the level of p=0.05 which suggested that the case group had a swollen *A* and *T*/*P*. But only *T*/*P* was significant after comparison at the level of corrected p value and power analysis. So, we can reach a conclusion that the case group has bigger tonsils than the control, and they may have swollen *T*/*P*s. This is in accordance with the earlier observation, for instance of Lowe and Peter's research [13], the obstruction caused by swollen *A* and *T*/*P* was the main reason of nocturnal sleep apnea. Özdemir [17] also reported that there was significant relationship between AHI and adenotonsillar hypertrophy. All the above studies clearly mandated the intervention with early and effective therapy of adenotonsillar hypertrophy in children with OSA [21].

As the most important element for sleep apnea in children, quantitative evaluation of *A*s and *T*/*P*s had always been the subject of intensive efforts of surgeons and other related doctors. Various methods for evaluation of *A* and *T*/*P* had been postulated by researchers [22–24]. Cephalometrics had been the preferred choice of orthodontists to evaluate the airway and craniofacial hard tissue, but now cone beam computed tomography (CBCT) has arisen much more interest in analysis of airway [25–27]. A visual and more accurate photograph with high image resolution can be obtained from CBCT. Moreover, the volume of airway can be calculated through CBCT. But due to the high cost and limited public cognition of the CBCT, it was not quite popular in our country. There are also some other researchers turned to alternatives, e.g., MRI, and other methods are being used in clinics [28]. We evaluated six different parameters of *A* and *T*/*P* according to different methods and a comparison between those was performed. The data suggested that *A* and *T*/*P* were the most sensitive parameters to evaluate the swollen tissues. A represented the width of *A* at the narrowest part of nasopharyngeal airway. T/P represented the ratio of radius of tonsil and width of oropharynx. The dimension of *A* and the ratio of *T*/*P* were sensitive because they represented the degree of air ventilation in nasopharynx and oropharynx, respectively.

Patients with sleep apnea were believed to have narrow airway according to some researchers, but the results of our data did not support this. The vertical and horizontal dimensions of soft palate, tongue, and airway were compared between the two groups, and statistical significant differences were absent. There are some potential explanations. Firstly, Only 15 patients took part in this study due to the low prevalence of pediatric OSA which resulted in the small sample size which is not enough to find the differences of the above mentioned dimensions. If given a larger sample size, the results may be different. Secondly, the cephalometry used in this study may be not quite sensitive and accurate to evaluate the airway and the surrounding soft tissues. The measurement of the parameters in two-dimensional cephalometry will unavoidably produce some errors, because it lacks the precision of three-dimensional (3D) imaging. The above method error may partially contribute to the absence of significant difference in airway dimensions. A higher quality 3D magnetic resonance imaging (MRI) and CBCT will surpass the two dimensional cephalometry in comparison of airway and soft tissues. There were also limitations to this study. We will endeavor to have more patients and alternate methods involved in the future studies.

Conclusions

The present study included 15 patients with documented OSA and 15 controls without any sleep problems according to their sleeping report. The patients and controls were strictly matched in sex and age. Comparison of the cephalometric parameters in two groups revealed that the facial type and airway shape of the OSA children differed from the ones in controls. The OSA children are featured by retrusive mandible, deficient chin, inferiorly positioned hyoid, and long lower face. *A* and *T*/*P* were the most sensitive parameters to evaluate the *A* and *T*/*P* in children at risk.

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Conflict of interest We declare that we have no conflict of interest in the authorship or publication of this contribution and no presentation at any conference.

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