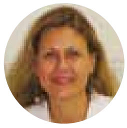
Correlation between cephalometric variables and obstructive sleep apnoea severity in children



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Abstract

Aim Alterations in craniofacial growth have been associated with obstructive sleep apnoea in children. The main objectives of this study were to analyse the correlation between cephalometric variables and Obstructive Apnea/Hypopnea Index (OAHI) in order to investigate if craniofacial features may influence the severity of obstructive sleep apnoea and to study the correlation between upper nasopharyngeal width and maxillomandibular skeletal discrepancy in sagittal and vertical plane.

Materials and methods Study Design: Correlations between cephalometric variables and obstructive sleep apnoea/hypopnea index and between upper airways space and maxillomandibular skeletal discrepancy were investigated. Forty-seven children with obstructive sleep apnoea diagnosed by overnight sleep study (polysomnography) underwent a lateral radiograph, orthodontic and ear-nose-throat examinations. Cephalometric analysis according to Kirjavainen has been performed to define skeletal and upper airways variables. Statistics: Spearman's correlation analysis was performed between OAHI and all cephalometric variables. Pearson's correlation analysis was performed between cephalometric variables of upper airway space and cephalometric variables related to maxillomandibular discrepancy. Chi-square test was used to compare occlusal features with adenoidal and tonsillar hypertrophy. Kruskal-Wallis rank test was used to compare OAHI with occlusal variables and adenotonsillar hypertrophy.

Results The results show a positive correlation between OAHI and maxillomandibular discrepancy measured by ANB angle (rho=0.32; p=0.023). A significant correlation was found between upper nasopharyngeal width and vertical maxillomandibular skeletal discrepancy: 1) ad1-PNS were correlated to Mandibular Plane/Sella-Nasion angle (r=-0.36; p=0.012), Palatal Plane/Mandibular Plane angle (r=-0.39; p=0.007), and Posterior-Anterior Facial Height % (r=0.29; p=0.045); 2) ad2-PNS was correlated to Palatal Plane/Mandibular Plane angle (r=-0.39; p=0.007). No statistically significant differences were found in non-parametric tests between OAHI and occlusal variables or adenoidal and tonsillar hypertrophy.

Conclusions The present study shows a significant correlation between maxillomandibular discrepancy and the severity of OSA. Moreover, the reduction of nasopharyngeal width was correlated to maxillomandibular hyperdivergent growth pattern. These results support the presence of a correlation between sleep-disordered breathing and craniofacial features even if the cause-effect relation is still unclear. Based on these evidences, we suggest the importance of orthodontic evaluation in the management of paediatric OSA.

KEYWORD Cephalometric analysis; Children; Obstructive sleep apnea; polysomnography; Upper airways space.

Introduction

Obstructive Sleep Apnea (OSA) is a breathing disorder characterised by repeated episodes of prolonged upper airway and/or intermittent complete obstruction that may disrupt normal sleep patterns and ventilation [American Thoracic Society, 1996].

The estimated prevalence of OSA in childhood ranges between 0.69 and 5.7% [Flores-Mir et al., 2013], and if left untreated OSA may result in severe complications such as cardiovascular, metabolic, neurocognitive and behavioural problems [Chervin et al., 1997].

Paediatric OSA is associated with daytime and nighttime symptoms, such as daytime sleepiness, headache upon awakening, snoring, nocturnal enuresis, restless sleep [Guilleminault and Stoohs, 1990].

The main risk factors for childhood OSA include adenotonsillar hypertrophy, obesity, neuromuscular disorders and craniofacial anomalies [Shintani et al., 1998]. Adenotonsillar hypertrophy is the most common reported aetiological factor [Guilleminault and Stoohs, 1990] and adenotonsillectomy represents the first-line treatment for childhood OSA. Recent evidences showed normalisation of polysomnographic findings in 79% of children after surgery [Marcus et al., 2013].

Obese children and those with a high preoperative Obstructive Apnea Hypopnea Index (OAHI), as well as children >7 years of age and/or with craniofacial disproportion are at highest risk of persistent OSA after adenotonsillectomy [Freidman et al., 2009].

Among the multiple risk factors, the presence of alterations in craniofacial growth has been recently associated with OSA in children [Di Francesco et al., 2012]. The most frequent craniofacial alterations reported in OSA children are retrognathia, midface hypoplasia, contraction of the upper jaw, relative macroglossia and anterior open bite [Defabianis, 2003; Robertson, 1996; Zucconi et al., 1999].

Two recent systematic reviews evidenced the association between maxillomandibular discrepancy and obstructive sleep apnoea, suggesting that children with OSA have more skeletal Class II and a dolichofacial mandibular growth direction compared to normal children [Flores-Mir et al., 2013; Katyal et al., 2013], but the statistical significance of these results could have marginal clinical relevance [Katyal et al., 2013].

Few studies investigated the correlation between OSA severity and the cephalometric variables in children. Moreover, clinical features and possible complications vary widely depending on the severity of the disease in children with OSA [Hunter et al., 2016].

The main aim of this study was to analyse the correlation between the cephalometric variables and OAHI to investigate if craniofacial features may influence the degree of severity of OSA; the secondary objective was to investigate the correlation between the upper airways spaces and the skeletal variables.

Materials and methods

Subjects

The study was conducted in accordance with the principles of the Declaration of Helsinki. Sixty-two consecutive children (age range 3-11 years) referred to the Dentistry Unit, the Otorhinolaryngology Unit and the Respiratory Unit of the "Bambino Gesù" Children's Hospital and Research Institute in Palidoro (Rome, Italy) between March 2014 and June 2014 were considered for the study. The patients were selected on the basis of the following inclusion criteria: reported OSA symptoms (such as snoring, gasping of air, apnoea events during the night), significant obstructive apnoea events (Obstructive Apnea Hypopnea Index - OAHI - ≥1.5) [Carroll et al., 1995] evaluated by an at-home overnight sleep study (polysomnography). Exclusion criteria were: genetic syndromes, recent acute infections of the upper airways or acute otitis media, previous history of orthodontic treatment or adenoidectomy and/or tonsillectomy. Based on these criteria, 15 children were excluded and 47 patients were included in the study. These subjects underwent orthodontic and Ear-Nose-Throat (ENT) examinations, including flexible fiberoptic nasopharyngoscopy, and lateral radiograph in order to study hard and soft tissues alterations of the craniofacial complex.

This study was approved by the ethics committee of Bambino Gesù Children's Research Hospital and Institute, Rome, Italy.

Overnight sleep study polysomnographic (PSG) Data

A portable Somtè/Siesta device (Compumedics, Abbotsford, Australia) was used for the overnight PSG, a nasal cannula for the recording of nasal pressure, thoraco-abdominal movements, tracheal sound, body position, pulse oximetry (SpO_2), and heart rate were also recorded.

The definition of respiratory events and cut-off values were taken from the current guidelines [Berry et al., 2015; Berry et al., 2012]. Obstructive apnoea was defined as the absence of nasal airflow, with continued chest wall and abdominal movements for at least two breaths. Central apnoea was defined as the absence of airflow with the cessation of respiratory effort, lasting more than 20 seconds or of shorter duration and associated with bradycardia and 3% oxygen desaturation; central apnoea occurring after gross body movements or after sighs was not considered as a pathological finding. Mixed apnoea was defined as an apnoea that usually begins as central and ends as obstructive according to changes in the chest, abdominal, and flow traces. Hypopnea was defined as a decrease in nasal airflow of at least 50% with a corresponding decrease in SpO_2 of at least 3%. The mixed-obstructive apnoea-hypopnea index (OHAI) was used to define OSA [Cohen et al., 2014; Beck and Marcus, 2009]. Children with OAHI presenting <1.5 events/hr of total sleep time were considered not to have OSA or to have simple snoring [Carroll et al., 1995]. Central apnoea index (CAI) <1 event/hr was considered as normal in children [Beck and Marcus, 2009]. The total sleep time was recorded as previously described [Morielli et al.,1996].

Mean, minimum SpO_2 values and the percentage of total sleep time spent with SpO_2 <90% were calculated. Desaturation index (DI) was defined as the number of events of SpO_2 drops (at least 3 per hour of total sleep time).

Because of the absence of electroencephalographic recordings, sleep and wakefulness were distinguished by means of regularity of cardiorespiratory signals, behavioural observations, and the subject's appearance on video. This method was previously validated and found to have overall agreement with conventional PSG for a sleep/wakefulness discrimination of 94% [Morielli et al., 1996]. Total sleep time (TST) was quantitated, and respiratory parameters were expressed as a percentage of TST. Minimum acceptable total sleep time was considered 6 hours [American Thoracic Society, 1996].

Orthodontic and ENT examination

All patients underwent a multidisciplinary evaluation. Dental parameters such as canine and molar class, presence of posterior cross bite, overjet and overbite were collected and analysed by the same orthodontist. Evaluation of tonsillar hypertrophy grading was performed by the same ENT physician according to Brodsky [Brodsky, 1989] and the adenoidal hypertrophy was expressed according to fiberendoscopic findings in 4 grades [Cassano et al., 2003] evaluated by flexible nasopharyngoscopy.

Cephalometric analysis

Lateral cephalometric radiographs were taken with the same Cephalix cephalostat at the Diagnostic Imaging Unit of the "Bambino Gesù" Children's Hospital in Palidoro (Rome, Italy). Radiographs were taken with the subjects standing, the head fixed in the cephalostat with ear rods and a support on the forehead, the teeth in the maximum intercuspal position, the lips in a relaxed position, and the head in the natural position.

Cephalometric tracings were performed by an operator blind to the PSG results using a computerised software (Deltadent-Piolla, Milan, Italy) and the measures of angles and distances were calculated. As cephalometric method, the Kirjavainen analysis [Kirjavainen and Kirjavainen, 2007] was used to assess the cephalometric variables as described in Table 1 and shown in Figure 1.

The error of measurement method was calculated from 14 randomly selected participants. All the measurements were reassessed by one examiner after a memory washout period

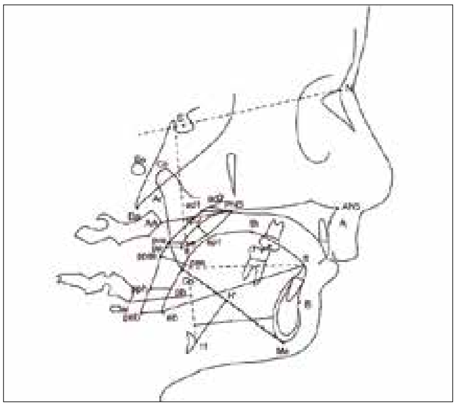

FIG. 1 The figure shows all cephalometric landmarks.

of at least 8 weeks. The error method for the cephalometric measurements was calculated using Dahlberg's formula [1940]. Systematic differences between duplicated measurements were tested using a paired Student's t-test with the type I error set at <0.1 [Houston, 1983].

Statistical analysis

Data analysis was carried out using the Statistical Analysis System (SAS 9.0; SAS Institute Inc., Cary, NC, USA). Numerical variables were expressed as means ± standard deviations, while nominal variables were expressed as frequencies.

A Spearman's correlation analysis was performed between OAHI and all cephalometrics variables. A Pearson's correlation analysis was performed in order to evaluate the correlation between cephalometric variables of upper airway space (ad1-PNS, ad2-PNS, pas-ppas) and cephalometric variables related to maxillomandibular discrepancy: Sella-Nasion-A point (SNA) angle, Sella-Nasion-B point (SNB) angle, A point-Nasion-B point (ANB) angle, Gonion-Menton (Go-Me) distance, Sella-Nasion/Mandibular Plane (SN-MP) angle, Palatal Plane/ Mandibular Plane (PP-MP) angle, Articular-Gonion-Menton (ArGoMe) angle, Posterior-Anterior (PA) facial height %.

Chi-square test was used to compare occlusal features with adenoidal and tonsillar hypertrophy. Kruskal-Wallis rank test was used to compare OAHI with occlusal variables and adenotonsillar hypertrophy. The level of significance was set at $p<0.05$.

A sample size of 47 achieves 80% power to detect a correlation of 0.40 (-0.40) considering the null hypothesis correlation of 0.00 using a two-sided hypothesis test with a significance level of 0.05.

Nasopharynx	
S-PNS	The distance of sella (S) to posterior nasal spine (PNS)
ad1-PNS	The distance of ad1 point to PNS. Ad1 is the intersection point of posterior pharyngeal wall and the line from PNS to Basion (Ba)
ad2-PNS	The distance of ad2 point to PNS. Ad2 is the intersection point of posterior pharyngeal wall and the line from the midpoint of the line from sella (S) to basion (Ba) to posterior nasal spine (PNS)
Oropharynx	
p-pp	The distance of the tip of soft palate (p) to horizontal counterpoint on posterior pharyngeal wall (pp)
pa	The distance of the intersection points on anterior and posterior pharingeal wall of the line from supramentale (B) to gonion (Go)
Hyoid bone	
H-H'	The distance from the most anterior and superior point of hyoid bone (H) perpendicular to mandibular plane (MP).
Maxilla	
SNA	The angle sella (S) to nasion (N) to subspinale (A)
Mandible	
SNB	The angle sella (S) to nasion (N) to supramentale (B)
ANB	The angle subspinale (A) to nasion (N) to supramentale (B)
Go-Me	The distance from gonion (Go) to menton (Me)
Facial heights	
S-Go	The distance from sella (S) to Gonion (Go)
N-Me	The distance from nasion (N) to menton (Me)
P-A face height	It is the ratio between S-Go/N-Me
(S-Go/N-Me)%	
Typology	
SN-MP	The angle nasion (N) to sella (S) to mandibular plane (MP).
PP-MP	The angle PP to MP. PP is the line from Anterior Nasal Spine (ANS) to PNS
Cranial base	
SN	The distance from sella (S) to nasion (N)
Growth prevision	
ArGoMe	The goniac angle Articular-Gonion to Gonion-Mention

TABLE 1 Cephalometric measurements and their definitions.

Results

Method error ranged, for linear measurements, from 0.1 to 1.1 mm and for angular measurements, from 0.4° and 0.8°. There was no systematic error for any of the cephalometric measurements (Student's t-test; P>0.1).

Forty-seven children (mean age±SD= 5.75±1.99 years), 23 males (48.9%) and 24 females (51.1%) were studied.

The descriptive analysis of cephalometric variables and OAHI score are summarised in Table 2.

The sample consisted of 10 patients (21.3%) with mild OSA (1.5≤OAHI<5), 9 patients (19.1%) with moderate OSA (5≤OAHI>10) and 28 patients (59.6%) with severe OSA (OAHI≥10) according to the classification of the American Thoracic Society [1996].

As for the occlusal variables, the sample consisted of 23 patients (48.9%) in Class I malocclusion, 20 patients (42.5%) in Class II malocclusion, 4 patients (8.5%) in Class III malocclusion and 18 children (38.3%) with posterior cross-bite. Twenty-two children (46.8%) showed tonsillar hypertrophy grade 2, 17 children (36.2%) tonsillar grade 3, and 8 children (17.0%) tonsillar grade 4. Two patients (4.2 %) had adenoidal hypertrophy grading grade 1, 17 patients (36.2%) adenoidal grading grade 2, 16 patients (34.0%) adenoidal grading 3 and 12 patients (25.5%) adenoidal grading 4.

Statistically significant positive correlations were found between OAHI (events/h) and maxillomandibular discrepancy expressed by the ANB angle (rho=0.32; p=0.023) (Table 3).

Statistically significant negative correlations were found between: 1) ad1-PNS distance and SN/MP angle (r=-0.36; p=0.0119), PP/MP angle (r=-0.39; p=0.007); 2) ad2-PNS distance and PP-MP (r=-0.32; p=0.026). A statistically positive correlation was found between ad1-PNS distance and P-A Facial Height % (r=0.29; p=0.045) (Table 4).

No statistically significant differences were found with non-parametric tests between OAHI and occlusal variables or adenoidal and tonsillar hypertrophy.

Discussion

Many cephalometric studies have previously evaluated the craniofacial features related to OSA as predisposing factors in the pathogenesis of the upper airway obstruction during sleep [Guilleminault and Stoohs, 1990] but few studies investigated the correlation between the OSA severity and the cephalometric variables in children [Ozdemir et al., 2004].

In our study, we used cephalometric analysis to define skeletal and airway dimensions. This was a limitation because of two reasons: firstly because lateral cephalograms are 2-D images of a 3-D anatomical complex, and secondly because some studies have shown that a change from upright to supine position alters the upper airway space in OSA patients [Ono et al., 1996]. Nevertheless, it was reported that pharyngeal airway area on a lateral cephalogram strongly correlates with volumetric data on cone-beam computed tomography (CBCT) images [Bronoosh and Khojastepour, 2015] and that lateral cephalogram can provide precise information in estimating tongue and pharynx volumes [Major et al., 2006; Malkoc et al., 2005] with a lower radiation dose.

In this study, OSA showed the same prevalence in male and female, as in previous findings reporting that in the prepubertal period there is no gender difference in the incidence of OSA [Alsubie and BaHammam, 2017]. Moreover our sample is underweight according to reported symptoms and signs of OSA in children [Marcus et al., 2012].

The main aim of our study was to analyse the correlation between cephalometric variables and OSA severity in children. Our results showed that increased OAHI was correlated with skeletal discrepancy expressed by ANB angle. The ANB angle is an important cephalometric variable to measure maxillomandibular discrepancy either in sagittal and in vertical directions. In sagittal direction, an increase of the ANB angle describes a skeletal Class II malocclusion and in the vertical direction it shows a mandibular clockward rotation. Therefore, we may suppose that a greater severity of the disease leads to an increased mouth breathing pattern that in turn strongly affects skeletal growth with Class II skeletal malocclusion and hyperdivergent growth pattern in children. Our results are different from those of Özdemir et al. [2004], showing that the gonial angle (Ar-Go-Me) and minimal posterior airway space, but not ANB angle, was correlated with OAHI.

When considering the relationship between skeletal cephalometric variables and upper airway space, we found the correlation between the reduction in upper nasopharyngeal width and the increase of vertical maxillomandibular cephalometric variables (SN/MP angle, PP/MP angle, P-A Facial Height). This finding may be related to mouth breathing in children with OSA that promote a posterior rotation of the mandible and the increase in both upper and lower goniac angles during the growth as previously reported [Flores-Mir et al., 2013; Zucconi et al., 1999]. Our results are partially

Cephalometric Variables	Mean ±SD	Range (min-max)
SNA(°)	81.5 ±4.2	73.8-91.9
SNB(°)	75.7±4.1	65.9-84.5
ANB(°)	5.7±2.6	-0.1-9.8
SN (mm)	61.8±5.5	47.2-73.7
Go-Me (mm)	59.4±7.0	45.1-76.6
MP/SN(°)	39.4±5.7	27.1-49.0
PP/MP(°)	31.7±5.8	21.4-44.7
Ar-Go-Me(°)	132.1±7.2	118.1-149.5
P-A face height (S-Go/N-Me)%	59.5±5.2	49.6-71.5
ad1-PNS (mm)	10.7±5.2	1-27.6
ad2-PNS (mm)	7.7±4.0	0.5-19.4
pas-ppas (mm)	16.5±3.2	9.9-25.4
OAHI (N° events/hrs)	12.6±9.1	1.2-42.3

TABLE 2 Cephalometric variables and Obstructive Apnea/Hypopnea Index expressed as mean and standard deviation (SD) and their ranges.

Variable	OAHI (events/h)
	rho
SNA (°)	0.10
SNB (°)	-0.15
ANB (°)	0.32*
MP/SN (°)	0.07
PP/MP (°)	0.04
Ar-Go-Me(°)	0.04
P-A face height (S-Go/N-Me)%	-0.90
ad1-PNS (mm)	-0.01
ad2-PNS (mm)	-0.01
pas-ppas (mm)	0.05
*p<0.05	

TABLE 3 Spearman's correlation coefficients (rho) between main cephalometric variables and Obstructive Apnea/Hypopnea Index (OAHI).

Variable	ad1-PNS (mm)	ad2-PNS (mm)	pas-ppas (mm)
SNA (°)	-0.06	-0.02	0.07
SNB (°)	0.02	-0.01	0.07
ANB (°)	-0.12	-0.02	0.03
MP/SN (°)	-0.36*	-0.31	-0.04
PP/MP (°)	-0.39*	-0.32*	-0.08
Ar-Go-Me (°)	-0.22	-0.21	0.16
P-A face height (S-Go/N-Me)%	0.29*	0.28	0.07

TABLE 4 Pearson's correlation coefficients (r) between main cephalometric variables related to maxillomandibular discrepancy and main cephalometric variables of upper airway space.

consistent with those of Ozdemir et al. [2004] that show adenoid hypertrophy severity positively correlated with ArGoGn angle.

Guilleminault et al. [1989] suggested that nasal breathing is very important during childhood for preventing alterations in craniofacial growth. Our results support the hypothesis that the reduction of the nasopharyngeal space could have an important role in the development of hyperdivergent growth pattern of maxillomandibular complex.

Conclusion

In conclusion, the present study shows a significant correlation between maxillomandibular discrepancy and the severity of OSA, and between the reduction of nasopharyngeal width and the increase of hyperdivergent growth pattern. These results support the presence of correlation between sleep-disordered breathing and craniofacial features even if the cause-effect role is still unclear. Based on these evidences, we suggest the importance of orthodontic evaluation in the management of paediatric OSA.

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Conflict of interest

the authors declare that they have no conflict of interest.

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