Journal of Dental Sciences (2017) xx, 1–8

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.e-jds.com

Journal of Dental Sciences

Original Article

The preliminary results of the differences in craniofacial and airway morphology between preterm and full-term children with obstructive sleep apnea

Yun-Chia Lian [a,b], Yu-Shu Huang [c,d], Christian Guilleminault [e], Kuang-Tai Chen [c], Michèle Hervy-Auboiron [f], Li-Chuan Chuang [a,b*], Aileen I. Tsai [a,b]

[a] *Department of Pediatric Dentistry, Chang Gung Memorial Hospital at Linkou, Taoyuan, Taiwan*
[b] *Graduate Institute of Craniofacial and Dental Science, College of Medicine, Chang Gung University, Taoyuan, Taiwan*
[c] *Department of Child Psychiatry and Sleep Center, Chang Gung Memorial Hospital and College of Medicine, Taoyuan, Taiwan*
[d] *Craniofacial Research Center, Chang Gung Memorial Hospital, Taoyuan, Taiwan*
[e] *Stanford University Sleep Medicine Division, Stanford, CA, USA*
[f] *Orthodontic Institute, Noisy-Lesec, France*

Received 15 March 2017; Final revision received 22 March 2017
Available online ■ ■ ■

KEYWORDS
preterm children;
obstructive sleep apnea;
craniofacial and airway morphology

Abstract *Background/purpose:* The prematurely born and obstructive sleep apnea (OSA) could affect craniofacial and airway growth. The purpose of this study is to compare the differences in craniofacial and airway morphology between preterm and full-term children both with OSA problem.
Materials and methods: The differences in craniofacial and airway morphology between preterm children and full-term children both with OSA problem during the prepubertal (age 6–10) and pubertal (age 11–14) period were measured using lateral cephalometric radiograph.
Results: In the prepubertal period, effective maxillary length, and length from Go to Gn were smaller in the preterm group (n = 6) compared to the full-term (n = 8). The length of the soft palate was smaller and the distance soft palate-posterior side of nasopharynx was longer in preterm children. During puberty, (1) position of maxilla relative to cranial base: there was an anteroposterior maxilla and a mandibular discrepancy, a convexity of facial profile, (2) the distance from point A to nasion perpendicular, the distance from Pog to nasion

* Corresponding author. Department of Pediatric Dentistry, Chang Gung Memorial Hospital at Linkou, No. 5, Fuxing St., Guishan Dist., Taoyuan City 333, Taiwan. Fax: +886 33281200x8320.
E-mail address: soleus34@cgmh.org.tw (L.-C. Chuang).

http://dx.doi.org/10.1016/j.jds.2017.03.005

perpendicular, and the ratio of effective maxillary length/effective mandibular length were smaller in the preterm group (n = 5) compare to the full-term (n = 6).

Conclusion: During prepuberty, the preterm children had a significantly shorter effective maxillary and mandibular length but the catch up growth resulted during the pubertal period in reduction in facial profile convexity and more important mandibular vertical growth toward a dolichocephalic profile. Due to preterm birth, OSA children have a different craniofacial morphology compared to the full-term. When using an oral device for passive myofunctional therapy, the treatment outcome maybe different.

Introduction

Pediatric sleep-disordered-breathing (SDB) is a common health problem in children and adolescents,[1–3] which includes upper airway resistance syndrome (UARS) and obstructive sleep apnea syndrome (OSA). OSA is the most prevalent clinical syndrome when considering SDB.[4] OSA may have a very negative impact on children's systemic health and development.[3,5,6] The pathophysiology of pediatric OSA is unclear, but craniofacial anomalies and abnormal anatomic development have been reported: Nasal obstruction with retrognathism and deformities of craniofacial structures, micrognathia, short and narrow cranial base, midfacial hypoplasia, macroglossia and hypotonia are all highly associated with pediatric OSA.[7–10] Preterm children have both a 70% incidence of OSA and a high rate of craniofacial anomalies such as shorter anterior cranial base, less convex skeletal profile, shorter maxillary length, oral defects such as high and narrow hard palate and dental arch, and significant growth failure compared to full-term children.[11–18] Most premature infants will have "catch-up growth" during adolescence, however.[13,16,19,20] Even though the incidence of OSA in preterm children is high, no associated study has investigated whether the craniofacial anomalies seen in premature children may relate to the incidence of OSA and the craniofacial change noted during the pubertal period.

The purpose of this study was to compare the differences in craniofacial and airway morphology between preterm children and full-term children both with OSA problems during the pre-pubertal and pubertal periods.

Materials and methods

The study protocol was approved by the Institutional Review Board (IRB 104-9308A3) of the Human Investigation Committee of Chang Gung Memorial Hospital and Chang Gung University. This study included 25 children with pediatric OSA (mean age, 9.8 ± 2.5 years; age range, 6–14 years; Table 1) diagnosed with OSA based on the results of polysomnography (PSG) in the Sleep Center at the Medical Center in northern Taiwan. The selection criteria obtained from the PSG results were as follows: (1) oxygen level in children: <94% during sleep; (2) Respiratory Disturbance Index [including apnea-hypopnea and respiratory-event-related-arousals] (RDI): ≥5 events/hr; and (3) Apnea-Hypopnea Index (AHI): ≥1 events/hr. Children were divided into two groups with two different ages (pre-pubertal {age 6–10} and pubertal {age 11–14}), and, based on their gestational ages, in "preterm " (less than 37 weeks) and "full-term". Children with epilepsy, head injury, severe developmental delay and mental retardation, schizophrenia, severe depression, and with in-ability to cooperate with the PSG-testing were excluded.

Table 1 Demographics of the subjects.

	Full-term (N = 14)	Preterm (N = 11)	Total (N = 25)	P-value
Sex, n				
Boys	12 (85.7%)	9 (81.8%)	21 (84%)	
Girls	2 (14.3%)	2 (18.2%)	4 (16%)	0.070[a]
Age (y)	9.7 ± 2.2	9.9 ± 3.0	9.8 ± 2.5	0.825[b]
Gestational age (week)	39.2 ± 1.3	33.7 ± 3.3	36.8 ± 3.7	<0.001[b,*]
Birth body weight (gm)	3432.9 ± 657.8	2292.5 ± 934.8	2931.1 ± 965.5	0.003[b,*]
Body weight (kg)	39.6 ± 20.4	37.0 ± 22.1	38.4 ± 20.7	0.529[b]
Body height (cm)	134.5 ± 17.7	135.0 ± 19.8	134.7 ± 18.2	0.978[b]
AHI	4.9 ± 5.5	4.3 ± 5.0	4.7 ± 5.2	0.622[b]
RDI	7.6 ± 6.4	7.0 ± 8.7	7.4 ± 7.2	0.636[b]

All data are listed as means and standard deviations.
[a] Chi-square test.
[b] Mann–Whitney test; *P < 0.05.

Please cite this article in press as: Lian Y-C, et al., The preliminary results of the differences in craniofacial and airway morphology between preterm and full-term children with obstructive sleep apnea, Journal of Dental Sciences (2017), http://dx.doi.org/10.1016/j.jds.2017.03.005

Table 2 Definitions of landmarks and reference lines used in cephalometric analysis.

Skeletal, degrees	
NSBa	Cranial base angle
Co-Go-Gn	Mandibular angle
SNA	Position of maxilla relative to cranial base
SNB	Position of mandible relative to cranial base
ANB	Anteroposterior maxilla and mandible discrepancy
SN-FH	Frankfort horizontal plane angle
SN-MP	Mandibular plane angle
SN-PP	Angle of SN plane and palatal plane
PP-MP	Angle of mandibular plane and palatal plane
N-A-Pg	Facial profile convexity
Ar-Go-Gn	Gonial angle
Skeletal, mm	
N-Ba	Length of cranial base
S-N	Anterior cranial base length
Nasal line	Distance ANS-Ba
Co-Gn	Length of mandible
S-Go	Posterior face height
N-Me	Anterior face height
S-Go/N-Me	The ratio of PFH/AFH
ANS-PNS	Length of nasal floor
Go-Gn	Length from Go to Gn
A-Nv	The distance from point A to nasion perpendicular
Pg-Nv	The distance from Pog to nasion perpendicular
AH-BH	The vector from AH to BH
Ar-A	Effective maxillary length
Ar-Gn	Effective mandibular length
Ar-A/Ar-Gn	The ratio of effective maxillary length/effective mandibular length
Airway, degrees	
PMi-PNS-ANS	Inferior angle of hard palate/soft palate
Airway, mm	
Hy-C3	Distance hyoid bone-C3
LSP	Length of soft palate
PNS-NPhp	Distance between PNS and posterior side nasopharynx
PMm-NPh	Distance soft palate-posterior side of nasopharynx
OPha-OPhp	Distance anterior side-posterior side of oropharynx
MinRGA	Minimal width of airway behind tongue perpendicular to posterior pharyngeal wall
HPha-HPhp	Distance anterior side-posterior side of hypopharynx
PMi-NL	Nasopharynx height
PNS-AD1	Distance from PNS to the nearest adenoid tissue measured along the line PNS-BA
PNS-AD2	Distance from PNS to the nearest adenoid tissue measured along the line perpendicular to S-BA

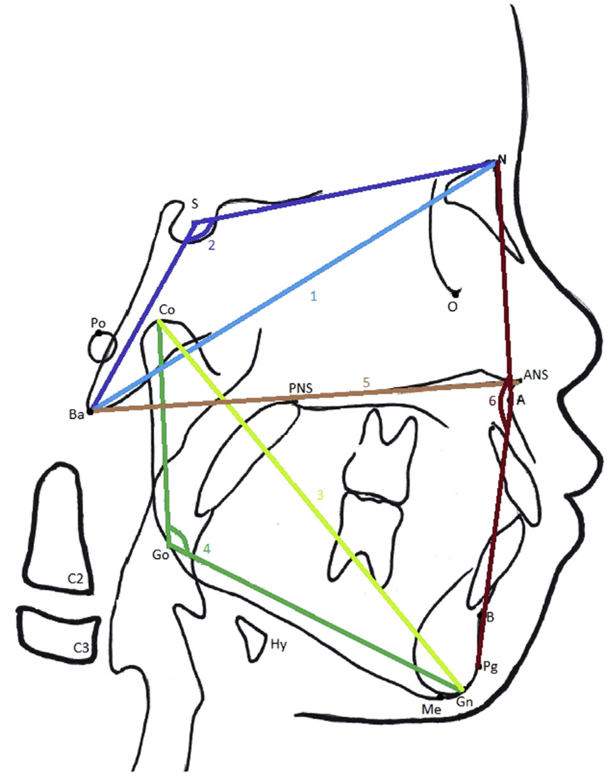

Figure 1 Craniofacial measurements. 1:NBa: Length of cranial base; 2: BaSN: Cranial base angle; 3: CoGn: Length of mandible; 4: CoGoGn: Mandibular angle; 5: Nasal line: Distance ANS-Ba; 6: N-A-Pg: Facial profile convexity.

Before conducting the study, the informed consent form had been signed by every participant and their parents. One lateral cephalometric radiograph was taken for each child. The participants had their heads kept in the natural position with Frankfort horizontal plane paralleled to the floor, teeth in centric occlusion and the lips closed in a relaxed position. Cephalograms were obtained on the same machine by the same operator. All cephalometric radiographs were hand-traced by a single investigator and another experienced dentist verified the cephalometric radiographs. The definitions of landmarks and reference lines used to perform the cephalometric analysis are provided in Table 2 and Figs. 1–3.[21] We assessed the error of the method by tracing and measuring 10 randomly selected radiographs one more time under the same conditions and performed calculations by using the intra class correlation coefficient. The average measure of intra class correlation coefficient was 0.78.

Statistical analyses were performed using the statistical software package SPSS- Released 2009. (PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc.). Descriptive statistics were presented as means and standard deviations. The chi-square test was used to test whether there were sex differences between full-term and preterm groups, while the Mann–Whitney test was used to test whether there were significance differences in cephalometric measurements among full-term and preterm groups. The level of significance was set at $P < 0.05$.

Please cite this article in press as: Lian Y-C, et al., The preliminary results of the differences in craniofacial and airway morphology between preterm and full-term children with obstructive sleep apnea, Journal of Dental Sciences (2017), http://dx.doi.org/10.1016/j.jds.2017.03.005

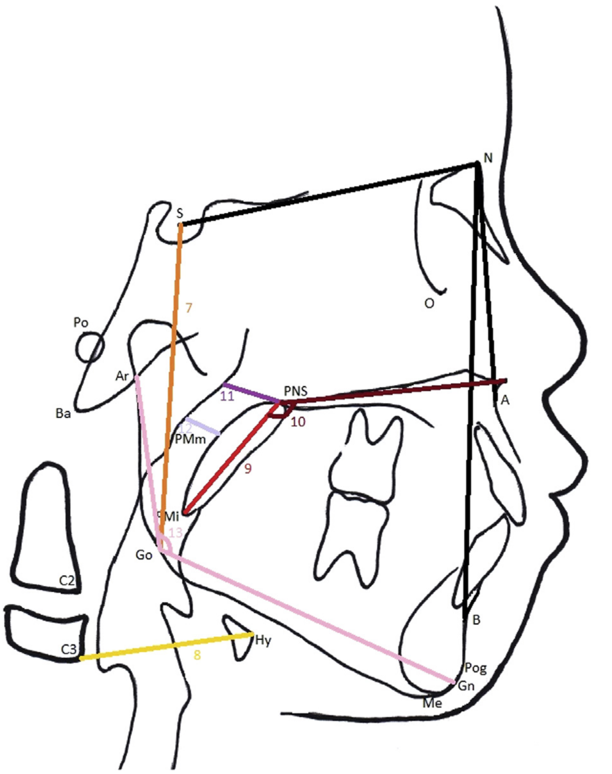

Figure 2 Craniofacial measurements. 7: SGo: Posterior face height; 8: Hy-C3: Distance hyoid bone-C3; 9: LSP: Length of soft palate; 10: PMi-PNS-ANS: Inferior angle of hard palate/soft palate; 11: PNS-NPhp: Distance between PNS and posterior side nasopharynx; 12: PMm-NPh: Distance soft palate-posterior side of nasopharynx; 13: Ar-Go-Gn: Gonial angle.

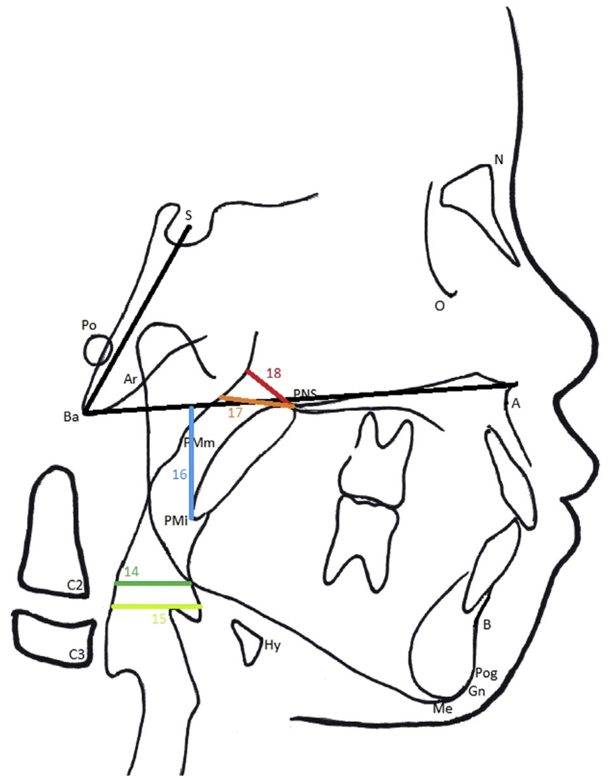

Figure 3 Craniofacial measurements. 14: OPha-OPhp: Distance anterior side-posterior side of oropharynx; 15: HPha-HPhp: Distance anterior side-posterior side of hypopharynx; 16: PMi-NL: Nasopharynx height; 17: PNS-AD1: Distance from PNS to the nearest adenoid tissue measured along the line PNS-BA; 18: PNS-AD2: Distance from PNS to the nearest adenoid tissue measured along the line perpendicular to S-BA.

Results

Twenty-five children were involved in this study and the demographic data of full-term and preterm children are shown in Table 1. There were no significant differences in age, body weight and body height distributions between the groups. Also no significant difference was shown in PSG data (AHI and RDI). The preterm group had significantly smaller gestational age and birth body weight.

Prepubertal subgroup (age 6–10): 8 children were full-terms and 6 children were premature-born (mean age, 9.7 ± 1.5 years; age range, 6–10 years; Table 3). There were no significant differences in age, PSG data (AHI and RDI), birth body weight and body height distributions between groups. The preterm group had significantly smaller gestational age and body weight. Pubertal group: (age 11–14), 6 children were full terms and 5 children premature-born (mean age, 12.2 ± 1.1 years; age range, 11–14 years; Table 4). There were again no significant differences in age, PSG data (AHI and RDI), body weight, or body height distributions between the groups. The preterm group had significantly smaller gestational age and birth body weight.

The results of cephalometric analysis between preterm and full-term groups are shown in Table 5 and Figs. 4 and 5. In the pre-pubertal group the effective maxillary length (Ar-A), and length from Go to Gn (Go-Gn) were smaller in preterm than in full-term children ($P < 0.05$). Also the length of the soft palate (LSP) was smaller and the distance soft palate-posterior side of nasopharynx (PMm-NPh) was longer in preterm children ($P < 0.05$). In the pubertal children, the position of the maxilla relative to cranial base (SNA), the anteroposterior maxilla and mandible discrepancy (ANB), the facial profile convexity (N-A-Pg), the distance from point A to nasion perpendicular (A-Nv), the distance from Pog to nasion perpendicular (Pg-Nv), and the ratio of effective maxillary length/effective mandibular length (Ar-A/Ar-Gn)were smaller in preterms compared to full-term children ($P < 0.05$). There were no significant differences in airway morphology during the pubertal period.

Discussion

Our results showed significantly more changes in preterm children during the pre-pubertal period, but a catch-up-growth of maxillary length, mandibular length and soft tissue occurs during puberty. But during the pubertal period, the preterm children have still less facial profile convexity and more mandibular vertical growth like dolichocephalic profile compared to the full-term children. Our

Please cite this article in press as: Lian Y-C, et al., The preliminary results of the differences in craniofacial and airway morphology between preterm and full-term children with obstructive sleep apnea, Journal of Dental Sciences (2017), http://dx.doi.org/10.1016/j.jds.2017.03.005

Table 3 Demographics of the subjects during the pre-pubertal period (6–10 y/o; N = 14).

	Full-term (N = 8)	Preterm (N = 6)	Total (N = 14)	P-value
Sex, n				
Boys	7 (87.5%)	5 (83.3%)	12 (85.7%)	
Girls	1 (12.5%)	1 (16.7%)	2 (14.3%)	0.049[a]*
Age (y)	9.7 ± 2.2	9.9 ± 3.0	7.9 ± 1.5	0.324[b]
Gestational age (week)	39.0 ± 1.4	33.5 ± 3.1	36.6 ± 3.6	0.002[b]*
Birth body weight (gm)	3216.3 ± 537.6	2137.6 ± 724.6	2882.4 ± 827.2	0.121[b]
Body weight (kg)	31.1 ± 11.8	21.6 ± 6.1	27.1 ± 10.6	0.038[b]*
Body height (cm)	128.5 ± 11.7	117.9 ± 7.9	125.2 ± 11.7	0.196[b]
AHI	2.9 ± 2.9	1.4 ± 1.4	2.3 ± 2.4	0.272[b]
RDI	5.1 ± 3.9	3.8 ± 1.6	4.5 ± 3.1	0.948[b]

All data are listed as means and standard deviations.
[a] Chi-square test.
[b] Mann-Whitney test; *P < 0.05.

Table 4 Demographics of the subjects during the pubertal period (11–14 y/o; N = 11).

	Full-term (N = 6)	Preterm (N = 5)	Total (N = 11)	P-value
Sex, n				
Boys	5 (83.3%)	4 (80.0%)	12 (81.8%)	
Girls	1 (16.7%)	1 (20.0%)	2 (18.2%)	0.020[a],*
Age (y)	11.7 ± 1.2	12.8 ± 0.4	12.2 ± 1.1	0.068[b]
Gestational age (week)	39.0 ± 1.4	33.5 ± 3.1	37.0 ± 3.9	0.005[b],*
Birth body weight (gm)	3721.3 ± 738.3	2118.8 ± 957.8	2993.1 ± 1157.7	0.011[b],*
Body weight (kg)	50.8 ± 25.0	55.5 ± 19.7	52.9 ± 21.8	0.715[b]
Body height (cm)	142.4 ± 22.0	152.2 ± 12.4	146.9 ± 18.2	0.465[b]
AHI	7.6 ± 7.2	7.8 ± 5.7	7.7 ± 6.2	0.715[b]
RDI	11.1 ± 7.8	13.5 ± 14.2	11.9 ± 9.5	1.000[b]

All data are listed as means and standard deviations.
[a] Chi-square test.
[b] Mann–Whitney test; *P < 0.05.

full-term children with have more of a class II pattern of growth with a retrusive mandible, where the distance (Ar-Gn) has not grown as much compared to preterms.

Additionally, insufficient sagittal development and more vertical mandibular growth was also noted in the preterm children. Similar results were shown in studies comparing craniofacial structures growth between preterm and full-term children regardless of OSA problem.[12–14,16,18–20] The differences may be related to a lower growth rate in preterm children. Preterm children showed significant growth failure in their early childhood as is well-documented in many studies: smaller head circumference, shorter height, lower body weight have been reported in preterm compared with full-term children.[11,13] High incidences of oral defects including high-arched and narrowing palate, prenormal occlusion, and palatal asymmetry have also been reported in preterm children.[13] The smaller cephalometric data of our preterm children compared to those in full-term children found in this study may thus be explained. These traits also are found in children with OSA.[22] Preterm OSA children have a significantly shorter cranial base and maxillary length. The cranial base may significantly influence a large amount of the craniofacial dimensions[23,24]; the decreased cranial base dimensions are associated with a decrease in pharyngeal airway size.[25] Therefore, it is possible that the smaller cranial base dimensions may have important implications in the pathogenesis of OSAS,[24] noted particularly in the preterm children.

In the OSA full-term group, normal SNA with small SNB and large ANB suggests that the mandible is more retrusive than the maxilla in relation to anterior cranial base; higher mandibular angle (SN-MP), longer anterior face height (N-Me) and smaller ratio of anterior and posterior face height (S-Go/N-Me) are associated with vertical growth skeletal type, which represents a more clock-wise rotation of the mandible as seen in adults with OSA.[26,27] Reduced intermaxillary relationship and longer soft palate have been reported in many previous studies related to children with OSA problems.[22,26,28,29]

Craniofacial morphology can be one of the predictors of the treatment outcome of oral appliance with mandible advancement in adult OSA patients.[27] Narrow minimal retroglossal airways, mandibular retrusion and short anterior

Table 5 Cephalometric analysis.

Measurement	Pre-pubertal (6–10 y/o; n = 14)			Pubertal (11–14 y/o; n = 11)		
	Full-term (n = 8)	Preterm (n = 6)	P-value	Full-term (n = 6)	Preterm (n = 5)	P-value
Skeletal, degrees						
SNBa	131.8 ± 5.0	130.6 ± 4.7	0.400	133.3 ± 5.3	138.8 ± 5.4	0.234
Co-Go-Gn	116.4 ± 4.6	118.5 ± 5.0	0.437	116.0 ± 8.1	115.4 ± 3.8	0.854
SNA	80.1 ± 3.8	81.3 ± 3.4	0.602	83.8 ± 3.8	76.4 ± 4.9	0.017*
SNB	76.1 ± 1.9	77.8 ± 2.3	0.207	77.7 ± 3.5	74.6 ± 2.8	0.140
ANB	4.1 ± 3.3	3.5 ± 2.9	0.517	6.1 ± 2.0	1.8 ± 2.5	0.008*
SN-FH	7.4 ± 2.7	6.7 ± 3.0	0.558	10.6 ± 2.9	9.3 ± 3.1	0.581
SN-MP	40.0 ± 3.0	38.3 ± 4.2	0.271	35.9 ± 2.4	41.4 ± 5.3	0.100
SN-PP	9.3 ± 2.2	7.2 ± 2.3	0.136	9.2 ± 3.2	11.3 ± 2.5	0.454
PP-MP	30.9 ± 3.4	31.3 ± 4.0	1.000	26.7 ± 3.0	29.5 ± 7.9	0.410
N-A-Pg	8.3 ± 7.3	6.8 ± 5.5	0.518	12.2 ± 3.9	2.4 ± 6.2	0.010*
Ar-Go-Gn	125.3 ± 3.3	123.5 ± 5.0	0.363	123.0 ± 5.7	122.5 ± 3.5	0.784
Skeletal, mm						
N-Ba	105.7 ± 7.1	98.8 ± 4.2	0.080	109.3 ± 5.1	111.7 ± 9.6	0.581
S-N	67.7 ± 4.6	64.3 ± 3.1	0.137	70.6 ± 3.3	70.8 ± 4.9	1.000
Nasal line	93.9 ± 4.4	89.3 ± 5.5	0.196	103.3 ± 5.0	114.5 ± 41.7	0.855
Co-Gn	107.4 ± 8.8	102.3 ± 4.7	0.243	115.9 ± 8.1	119.3 ± 8.9	0.584
ANS-PNS	48.4 ± 4.5	47.0 ± 3.5	0.363	54.9 ± 3.9	51.4 ± 7.8	0.566
S-Go	71.6 ± 3.8	71.9 ± 3.6	0.746	83.5 ± 9.0	79.0 ± 10.1	0.582
N-Me	118.3 ± 6.2	113.8 ± 7.4	0.331	128.2 ± 12.9	131.3 ± 8.8	0.714
S-Go/N-Me	0.60 ± 0.02	0.63 ± 0.03	0.116	0.65 ± 0.02	0.59 ± 0.04	0.078
Go-Gn	71.6 ± 3.9	66.3 ± 4.2	0.027*	76.6 ± 6.4	81.0 ± 6.3	0.233
A-Nv	−2.6 ± 4.2	−1.4 ± 5.4	0.846	4.9 ± 5.0	−4.3 ± 3.9	0.018*
Pg-Nv	−13.1 ± 4.8	−9.7 ± 8.0	0.432	1.9 ± 7.2	−10.1 ± 4.8	0.011*
AH-BH	8.9 ± 3.5	6.3 ± 3.0	0.269	7.0 ± 2.4	6.0 ± 2.8	0.462
Ar-A	82.2 ± 4.3	76.7 ± 3.2	0.020*	89.8 ± 5.1	86.1 ± 10.4	1.000
Ar-Gn	101.8 ± 6.4	98.7 ± 7.4	0.401	110.8 ± 7.3	113.1 ± 10.2	0.715
Ar-A/Ar-Gn	0.81 ± 0.36	0.78 ± 0.04	0.219	0.80 ± 0.02	0.76 ± 0.04	0.044*
Airway, degrees						
PMi-PNS-ANS	120.1 ± 33.3	129.1 ± 8.4	0.796	120.1 ± 33.3	129.1 ± 8.4	1.000
Airway, mm						
Hy-C3	33.5 ± 4.0	30.1 ± 2.5	0.080	36.6 ± 3.3	39.4 ± 4.7	0.268
LSP	30.6 ± 3.1	21.5 ± 9.9	0.010*	35.9 ± 4.4	34.0 ± 5.1	0.522
PNS-NPhp	19.6 ± 5.2	15.0 ± 4.7	0.217	19.5 ± 7.5	16.7 ± 5.1	0.410
PMm-NPh	8.1 ± 5.0	13.3 ± 2.4	0.038*	12.7 ± 5.4	12.3 ± 3.0	0.855
OPha-Ophp	10.1 ± 3.5	12.1 ± 2.5	0.217	11.8 ± 3.1	11.1 ± 2.2	0.582
minRGA	10.0 ± 2.9	13.3 ± 2.7	0.080	12.8 ± 2.5	11.6 ± 3.0	0.518
HPha-HPhp	11.1 ± 4.1	12.7 ± 3.0	0.331	12.6 ± 4.3	17.3 ± 3.4	0.082
PMi-NL	26.8 ± 6.8	26.3 ± 6.4	0.897	31.6 ± 2.9	36.3 ± 8.3	0.271
PNS-AD1	18.5 ± 3.7	18.3 ± 5.9	0.948	17.2 ± 5.8	16.9 ± 5.7	0.927
PNS-AD2	13.3 ± 2.5	13.4 ± 4.13.7	0.795	15.3 ± 5.1	14.2 ± 4.3	0.784

Mann–Whitney test; *P < 0.05.

face heights have better treatment outcome with oral appliances.[27] Due to premature birth, preterm OSA children (dolichocephalic profile) have a totally different craniofacial morphology compared to full-term individuals (class II profile with retrognathic mandible), and the treatment outcome of oral appliance could be different for full-term individuals. Further studies will be needed to compare the treatment outcome of oral appliance between these two groups of children.

There are some limitations to our study. First, we had few girls. Second, the sample size was small and could not be matched year-by-year for age. However, this study is the first to report different craniofacial findings for preterm and full-term children with OSA during the pre-pubertal and pubertal periods.

In conclusion, during pre-puberty, the preterm children had a significantly shorter effective maxillary (Ar-A) and mandibular length (Go-Gn), but the catch-up growth resulted during the pubertal period in reduction in facial profile convexity (ANB, N-A-Pg) and more importantly, mandibular vertical growth toward a dolichocephalic profile. Also the full-term children tended to be more

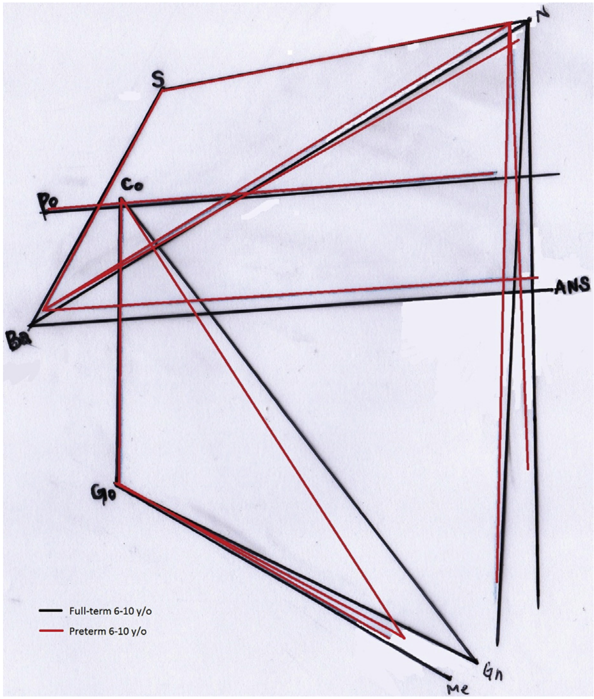

Figure 4 The superimposition of cephalometric analysis between preterm and full term groups (6–10 y/o).

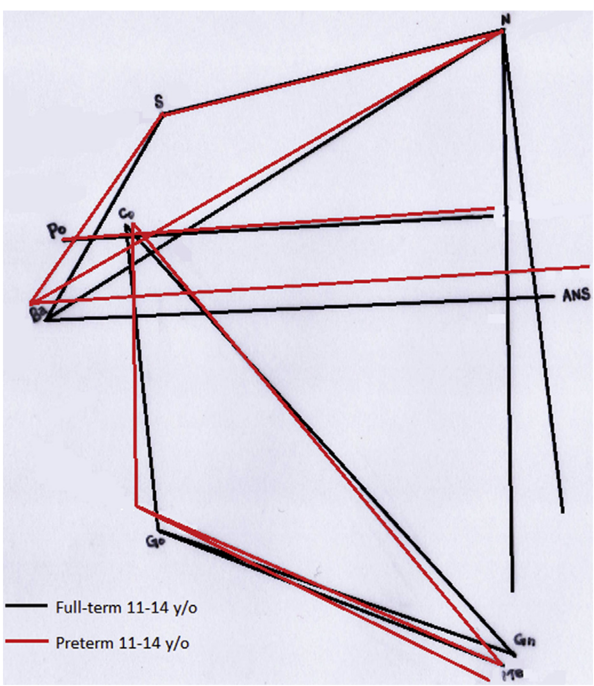

Figure 5 The superimposition of cephalometric analysis between preterm and full term groups (11–14 y/o).

mandibular retrognathic during puberty relative to those who had preterm births. Due to preterm birth, OSA children have a different craniofacial morphology compared to the full-term children with OSA. When using an oral device for a passive myofunctional therapy, the treatment outcome maybe different.

Conflict of interest

The authors have no conflicts of interest relevant to this article.

Acknowledgment

This research was supported by Chang Gung Memorial Hospital grant #: CRRPG5C0172 and 173 to YS Huang. We thank Prof. FM Hwang for help with statistical analysis.

References

1. Huynh NT, Desplats E, Almeida FR. Orthodontics treatments for managing obstructive sleep apnea syndrome in children: a systematic review and meta-analysis. *Sleep Med Rev* 2016;25:84–94.
2. Katyal V, Pamula Y, Martin AJ, Daynes CN, Kennedy JD, Sampson WJ. Craniofacial and upper airway morphology in pediatric sleep-disordered breathing: systematic review and meta-analysis. *Am J Orthod Dentofac Orthop* 2013;143:20–30.
3. Capua M, Ahmadi N, Shapiro C. Overview of obstructive sleep apnea in children: exploring the role of dentists in diagnosis and treatment. *J Can Dent Assoc* 2009;75:285–9.
4. Elden LM, Wetmore RF, Potsic WP, Fairbanks D, Mickelson S, Woodson B. Snoring and obstructive sleep apnea in children. In: Fairbanks DNF, ed. *Snoring and obstructive sleep apnea*, 3rd ed. USA: Philadelphia: Lippincott Williams & Wilkins, 2003:246–7.
5. Bahammam A. Obstructive sleep apnea: from simple upper airway obstruction to systemic inflammation. *Ann Saudi Med* 2011;31:1–2.
6. Lal C, Strange C, Bachman D. Neurocognitive impairment in obstructive sleep apnea. *Chest* 2012;141:1601–10.
7. Zucconi M, Caprioglio A, Calori G, et al. Craniofacial modifications in children with habitual snoring and obstructive sleep apnoea: a case-control study. *Eur Respir J* 1999;13:411–7.
8. Löfstrand-Tideström B, Thilander B, Ahlqvist-Rastad J, Jakobsson O, Hultcrantz E. Breathing obstruction in relation to craniofacial and dental arch morphology in 4-year-old children. *Eur J Orthod* 1999;21:323–32.
9. Zang YH, Chen J. Study on differences among sagittal facial types, upper airway width and hyoid position of children with mixed dentition. *Med J Qilu* 2009;24:340–2.
10. Wei Y, Cai Z, Qian Y. Cephalometry study of craniofacial and upper airway in boys with OSAS. *Shanghai Kou Qiang Yi Xue* 2003;12:3–6.
11. Huang YS, Guilleminault C. Pediatric obstructive sleep apnea and the critical role of oral-facial growth: evidences. *Front Neurol* 2012;3:1–7.
12. Paulsson L, Bondemark L, Söderfeldt B. A Systematic Review of the consequences of premature Birth on palatal morphology, dental occlusion, tooth-crown dimensions, and Tooth maturity and eruption. *Angle Orthod* 2004;74:269–79.
13. Paulsson L, Bondemark L. Craniofacial morphology in prematurely born children. *Angle Orthod* 2009;79:276–83.
14. Paulsson L, Söderfeldt B, Bondemark L. Malocclusion traits and orthodontic treatment needs in prematurely born children. *Angle Orthod* 2008;78:786–92.
15. Zettergren-Wijk L, Forsberg CM, Linder-Aronson S. Changes in dentofacial morphology after adeno-/tonsillectomy in young children with obstructive sleep apnoea—a 5-year follow-up study. *Eur J Orthod* 2006;28:319–26.
16. Farooqi A, Hägglöf B, Sedin G, Gothefors L, Serenius F. Growth in 10- to 12-year-old children born at 23 to 25 weeks gestation

in the 1990s: a Swedish national prospective follow-up study. *Pediatrics* 2006;118:1452—65.
17. Korobkin R, Guilleminault C. Neurologic abnormalities in nearmiss for sudden infant death syndrome infants. *Pediatrics* 1979;64:369—74.
18. Daily DK, Kilbride HW, Wheeler R, Hassanein R. Growth patterns for infants weighing less than 801 grams at birth to 3 years of age. *J Perinatol* 1994;14:454—60.
19. Stjernqvist K, Svenningsen N. Ten-year follow-up of children born before 29 gestational weeks: health, cognitive development, behaviour and school achievement. *Acta Paediatr* 1999;88:557—62.
20. Ford GW, Doyle LW, Davis NM, Callanan C. Very low birth weight and growth into adolescence. *Arch Pediatr Adolesc* 2000;154:778—84.
21. Tanon-Anoh MJ, Kouassi YM, Yoda M, et al. Craniofacial modifications in Ivorian melanoderm children with chronic retronasal obstruction. *Int J Pediatr Otorhinolaryngol* 2014;78:588—92.
22. Pirila-Parkkinen K, Pirttiniemi P, Nieminen P, Tolonen U, Pelttari U, Lopponen H. Dental arch morphology in children with sleep-disordered breathing. *Eur J Orthod* 2009;31:160—7.
23. Enlow DH, Kuroda T, Lewis AB. The morphological and morphogenetic basis for craniofacial form and pattern. *Angle Orthod* 1971;41:161—88.
24. Li KK, Kushida C, Powell NB, Riley RW, Guilleminault C. Obstructive sleep apnea syndrome: a comparison between Far-East Asian and white men. *Laryngoscope* 2000;110:1689—93.
25. Steinberg B, Fraser B. The cranial base in obstructive sleep apnea. *J Oral Maxillofac Surg* 1995;53:1150—4.
26. Kapsimalis F, Kryger M. Gender and obstructive sleep apnea syndrome, Part 1 clinical features. *Sleep* 2002;25:409—16.
27. Shen HL, Wen YW, Chen NH, Liao YF. Craniofacial morphologic predictors of oral appliance outcomes in patients with obstructive sleep apnea. *J Am Dent Assoc* 2012;143:1209—17.
28. Katyal V, Pamula Y, Daynes CN, et al. Craniofacial and upper airway morphology in pediatric sleep-disordered breathing and changes in quality of life with rapid maxillary expansion. *Am J Orthod Dentofac Orthop* 2013;144:860—71.
29. Deng J, Gao X. A case-control study of craniofacial features of children with obstructed sleep apnea. *Sleep Breath* 2012;16:1219—27.

Please cite this article in press as: Lian Y-C, et al., The preliminary results of the differences in craniofacial and airway morphology between preterm and full-term children with obstructive sleep apnea, Journal of Dental Sciences (2017), http://dx.doi.org/10.1016/j.jds.2017.03.005