DOI: 10.1111/j.1365-263X.2011.01117.x

INTERNATIONAL JOURNAL OF PAEDIATRIC DENTISTRY

Changes in facial morphology after adenotonsillectomy in mouth-breathing children

SARA E. M. MATTAR[1], FABIANA C. P. VALERA[2], GISELE FARIA[3], MIRIAM A. N. MATSUMOTO[4] & WILMA T. ANSELMO-LIMA[2]

[1]Department of Orthodontics of Dentistry School of Ribeirão Preto, University of São Paulo, São Paulo, Brazil, [2]Department of Ophthalmology, Otorhinolaryngology and Head and Neck Surgery of Medical School of Ribeirão Preto, University of São Paulo, São Paulo, Brazil, [3]Department of Restaurative Dentistry of Araraquara, Dental School São Paulo State University, São Paulo, Brazil, and [4]Department of Orthodontics of Dentistry School of Ribeirão Preto, University of São Paulo, São Paulo, Brazil

International Journal of Paediatric Dentistry 2011; 21: 389–396

Background. Morphological and dentofacial alterations have been attributed to impaired respiratory function.
Objective. To examine the influence of mouth breathing (MB) on children facial morphology before and after adenoidectomy or adenotonsillectomy.
Methods. Thirty-three MB children who restored nasal breathing (NB) after surgery and 22 NB children were evaluated. Both groups were submitted to lateral cephalometry, at time 1 (T1) before and at time 2 (T2) 28 months on average postoperatively.
Results. Comparison between the MB and NB groups at T1 showed that mouth breathers had higher inclination of the mandibular plane; more obtuse gonial angle; dolichofacial morphology; and a decrease in the total and inferior posterior facial heights. Twenty-eight months after the MB surgical intervention, they still presented a dolichofacial morphologic pattern. During this period, MB altered the face growth direction and decreased their mandible plane inclination, with reduction in the SN.GoGn, PP.MP, SNGn, and ArGo.GoMe parameters as well as an increase in BaN.PtGn.
Conclusion. After the MB rehabilitation, children between 3 and 6 years old presented significant normalization in the mandibular growth direction, a decrease in the mandible inclination, and an increase in the posterior facial height. Instead, they still persisted with a dolichofacial pattern when compared with nasal breathers.

Introduction

Children nasal obstruction is closely related to the changes in the posture of the head and mandible, orofacial and neck tonicity, and craniofacial morphology[1]. Adenotonsillar hypertrophy and allergic rhinitis are the most common causes of children respiratory obstruction, which leads to mouth breathing[2], and the association of these two main causes is frequent, which exacerbates the respiratory symptoms[2,3].

The effect of tonsillectomy on craniofacial growth has been extensively studied[4,5]. The change in the mode of children breathing during the facial growth spurt favours the craniofacial and dentofacial development and promotes a more horizontal mandible growth direction[5,6]. The forward rotation of the mandible leads to significant improvement in upper and lower incisor inclination, anterior and posterior vertical face heights, and dental arch width. Modifications in the nasopharyngeal airway space and the mandible plane inclination are also observed[4–8]. Moreover, the children who were submitted to adenotonsillectomy presented a myofunctional improvement in labial posture and tonicity, tongue or lip interposition during deglutition and mastication 2 years after surgery, in a prospective study[9].

To establish how the respiratory obstruction affects dentofacial development, mouth breathing preschool children (MB) were compared

Correspondence to:
M. A. N. Matsumoto, Department of Orthodontics of Dentistry School of Ribeirão Preto – University of São Paulo, Av. do Café s/n, B. Monte Alegre, Ribeirão Preto, SP 14040-904, Brazil.
E-mail: manakane@forp.usp.br

with nasal breathing (NB) children. Also, MB group was submitted to adenoidectomy or adenotonsillectomy, and their cephalometric evaluation before surgery was compared with that at 28 months on average postoperatively.

Methods

This quasi-experimental study with an untreated control group and a pretest and post-test group was approved by the Human Ethics Committee on Research of the Dental School of Ribeirão Preto, University of São Paulo, Brazil (Process no. 2000.1.483.58.5). The children were selected from the Rhinosinusology Outpatient Clinics – School of Medicine of Ribeirão Preto, and from the dental treatment at the Pedodontics Clinic, School of Dentistry of Ribeirão Preto; both of them were from the University of São Paulo. All patients underwent otorhinolaryngological and orthodontics evaluation.

Seventy-three mouth or NB children aged between 3 and 6 were included in this study. According to breathing pattern diagnosis, they were separated into two groups. The experimental group had 44 MB, with airway obstruction because of tonsil hypertrophy. The control group had 29 NB children with no airway obstruction. Children with compromised teeth and dental arch, septal deviation, previous history of respiratory surgery, and/or orthodontic treatment were excluded from the study. The patients were of both genders and from both black and white backgrounds.

The otorhinolaryngological evaluation was performed by the same doctor. The clinical evaluation included the oroscopy, which evaluated the tonsil hypertrophy using the Brodsky and Kock[10] criteria; anterior rhinoscopy; otoscopy; lateral skull radiography, which evaluated the hypertrophy of the pharynx tonsils, using the Cohen and Konak[11] criteria.

The patients were forward to the orthodontic evaluation, which consisted in lateral cephalometric radiographic analysis (considered time 1 – T1). The dentofacial structures and the soft tissues were traced by hand, and the following angular and linear cephalometric measurements were obtained from the cephalometric tracings (Fig. 1):

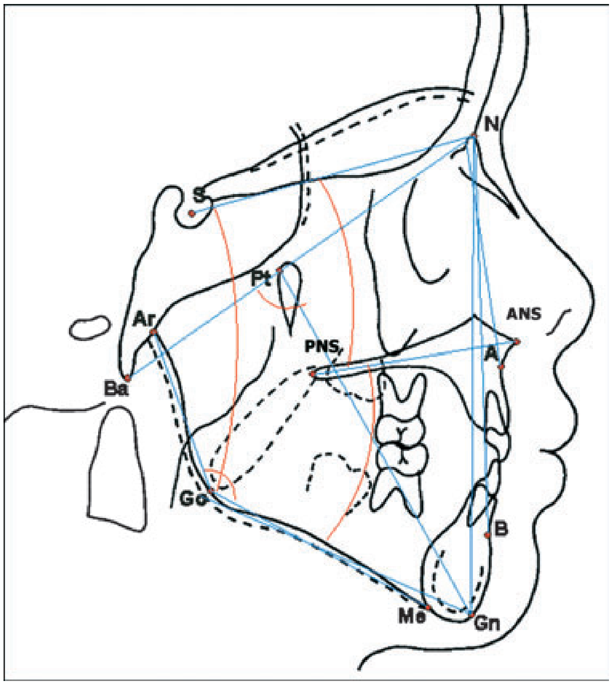

Fig. 1. Trace of the dentofacial anatomical structures, soft tissues, and cephalometric points used in this study. Cephalogram illustrating the angular cephalometric measurements.

1. SNA angle: the anteroposterior position between the maxilla and the cranial base.
2. SNB angle: the anteroposterior position between the mandible and the cranial base.
3. ANB angle: the anteroposterior relationship between the maxilla and the mandible.
4. SN.GoGn angle: the degree of the mandible plane inclination in relation to the anterior cranial base.
5. SN.PP angle: the degree of the maxilla inclination in relation to the anterior cranial base.
6. PP.MP angle: relates the maxilla to the mandible in the vertical plane.
7. ArGo.GoMe angle (gonial angle): establishes the degree of the ramus inclination in relation to the mandible body.
8. SNGn angle: corresponds to face growth direction.
9. BaN.PtGn angle: describes the variation in face height and face depth.
10. N-Me: linear measure corresponding to the total anterior facial height.

11 N-ANS: describes the upper anterior facial height.
12 ANS-Me: describes the lower anterior facial height.
13 S-Go: linear measure corresponding to the total posterior facial height.
14 S-Ar: describes the upper posterior facial height.
15 Ar-Go: describes the lower posterior facial height.

After both otorhinolaryngologic and orthodontic evaluation, children of the MB group underwent adenoidectomy or adenotonsillectomy. Clinical otolaryngological examinations were repeated 1, 6, 12, and 24 months postoperatively. Children with moderate allergic rhinitis were medicated and continued participating in the MB group of the study, whereas individuals with recurrent pharyngeal tonsils or with persistent respiratory symptoms were excluded from the investigation. The cephalometric data were repeated in average 28 months after surgery in the MB (time 2 – T2) and in the NB groups.

Data were analysed by the statistic program GraphPad Prism 5 (GraphPad Software Inc., San Diego, CA, USA). First, the values were analysed by the distribution (D'Agostino–Pearson normality test), and all data were distributed normally. The Student's *t*-test was used for the comparison of the MB and NB group average cephalometric measurements, and the paired *t*-test was used to compare the measurements within each group at times T1 and T2. The difference was considered statistically relevant when *P* was set <0.05.

Results

Eighteen patients were excluded from the initial sample because of one of the following reasons: follow-up track, loss of teeth or the dental arch integrity loss, orthodontic treatment, and persistent or recurrent respiratory symptoms. Thus, the final sample comprised 55 children, 33 of mouth breathers (MB) and 22 nasal breathers. The mean age in the MB group was 4 years and 8 months at T1 and 7 years and 2 months at T2. The mean age in the NB group was 5 years and 1 month at T1 and 7 years and 4 months at T2.

Table 1. Comparison of the cephalometric measurements obtained for the MB and NB groups at time T1 through Student's *t*-test.

	Group MB (T1)		Group NB (T1)		
Measurement	**Average**	**SD**	**Average**	**SD**	***P***
SNA (°)	81.6	3.9	82.8	4.6	ns
SNB (°)	75.8	2.8	77.7	5.1	ns
ANB (°)	5.8	2.3	5.4	1.7	ns
SN-GoGn (°)	41.2	4.8	36.6	4.8	<0.001
SN-PP (°)	6.1	3.1	6.0	3.8	ns
PP-MP (°)	37.2	4.2	32.7	6.0	0.002
ArGo-GoMe (°)	136.9	3.6	131.3	3.2	<0.0001
SN-Gn (°)	70.8	3.5	69.2	4.8	ns
BaN-PtGn (°)	84.2	3.9	88.2	3.2	<0.0001
N-Me (mm)	100.1	5.2	99.0	4.8	ns
N-ANS (mm)	43.1	2.9	43.1	2.8	ns
ANS-Me (mm)	60.1	3.8	59.2	3.5	ns
S-Go (mm)	58.2	3.3	60.4	4.4	0.039
S-Ar (mm)	27.4	2.8	28.2	3.4	ns
Ar-Go (mm)	33.3	2.7	35.8	4.4	0.012

ns, nonsignificant; SD, standard deviation; MB, mouth breathing; NB, nasal breathing.

Table 1 compares the MB and NB groups at time T1. MB group presented a higher inclination of the mandible when compared with the cranial base (SN.GoGn) and the palatal plane (PP.MP) as well, a more obtuse gonial angle (ArGo.GoMe), a significant decrease in the posterior facial height (S-Go) because of smaller mandibular ramus height (Ar-Go). Besides that, the BaN.PtGn was significantly lower in the MB group, demonstrating that this group presented a predominant dolichofacial morphology when compared with NB. The other parameters did not reach the statistical significance (Figs 2 and 3).

At T2, the comparison of the cephalometric measurements revealed that only the parameter BaN.PtGn was statistically lower in MB, which demonstrated that MB children were still predisposed to dolichofacial morphology after the surgery (Table 2). All other measures were statistically similar to the postoperative evaluation (Figs 4 and 5).

The evolution of each group is demonstrated in Table 3. The results showed that there was a significant increase in the linear measures for NB group (ArGo.GoMe, N-Me, N-ANS, ANS-Me, S-Go, S-Ar, and Ar-Go), which can be explained by the facial growth during the analysed period. The angular measurements, however, remained stable.

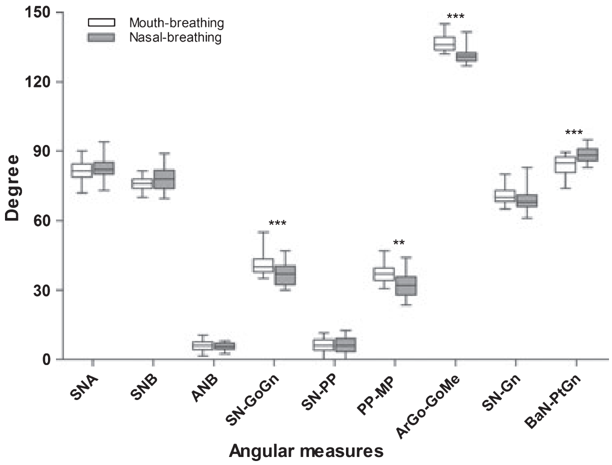

Fig. 2. Box plot. Comparison of the angular cephalometric measurements obtained for the mouth breathing and nasal breathing groups at time T1 through Student's *t*-test. ***$P < 0.001$; **$P < 0.01$.

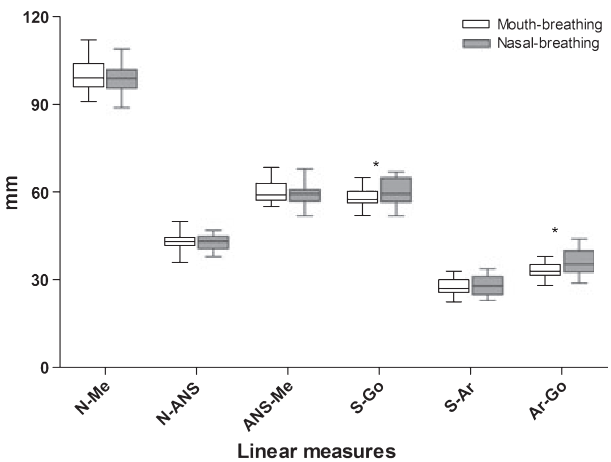

Fig. 3. Box plot. Comparison of the linear cephalometric measurements obtained for the mouth-breathing children and nasal-breathing groups at time T1 through Student's *t*-test. *$P < 0.05$.

Table 2. Comparison of the cephalometric measurements obtained for the MB and NB groups at time T2 through Student's *t*-test.

	Group MB (T2)		Group NB (T2)		
Measurement	Average	SD	Average	SD	*P*
SNA (°)	82.5	3.8	82.2	4.5	ns
SNB (°)	76.6	3.1	77.6	4.2	ns
ANB (°)	5.8	2.0	5.0	1.7	ns
Sn-GoGn (°)	38.8	5.1	36.6	5.3	ns
SN-PP (°)	6.3	3.5	6.4	3.3	ns
PP-MP (°)	34.5	4.4	32.1	6.1	ns
ArGo-GoMe (°)	133.4	3.6	134.2	5.4	ns
SN-Gn (°)	69.6	3.5	69.1	5.2	ns
BaN-PtGn (°)	86.0	3.9	89.0	3.0	0.004
N-Me (mm)	105.6	5.1	105.5	5.5	ns
N-ANS (mm)	46.4	3.1	46.7	2.7	ns
ANS-Me (mm)	62.2	3.3	61.4	4.1	ns
S-Go (mm)	63.0	3.5	64.1	5.8	ns
S-Ar (mm)	29.9	2.3	30.5	2.9	ns
Ar-Go (mm)	35.9	3.0	37.5	4.6	ns

ns, nonsignificant; SD, standard deviation; MB, mouth breathing; NB, nasal breathing.

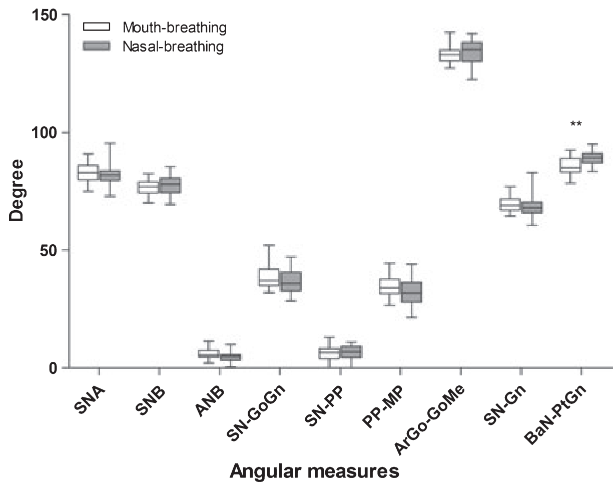

Fig. 4. Box plot. Comparison of the angular cephalometric measurements obtained for the mouth-breathing children and nasal-breathing groups at time T2 through Student's *t*-test. **$P < 0.01$.

At the MB group evaluation, the linear cephalometric parameters (N-Me, N-ANS, ANS-Me, S-Go, S-Ar, and Ar-Go) increased during the T2 period. A statistically significant alteration, however, at the angular measures SNA, SN.GoGn, PP.MP, ArGo.GoMe, SNGn, BaN.PtGn between T1 and T2 was observed. The average values reduction of SN.GoGn, PP.MP, SNGn, and ArGo.GoMe and the increase in the average value of BaN.PtGn revealed a decrease in the mandibular plane inclination as well as a forward rotation of the mandible in the MB group after surgery. It is noteworthy that the values of SNA, SN.GoGn, PP.MP, SNGn, and BaN.PtGn changed significantly only in the MB group and not in the NB group.

The final evaluation compared the variation of the average cephalometric values between the two times, in MB and NB groups (Table 4). There was a significant statistical difference between the means for the SNA, SN.GoGn, PP.MP, and ArGo.GoMe values between the groups, which revealed a higher

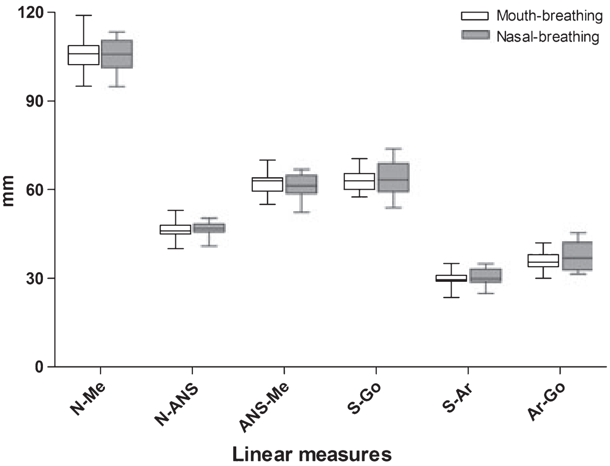

Fig. 5. Box plot. Comparison of the linear cephalometric measurements obtained for the mouth-breathing children and nasal-breathing groups at time T2 through Student's *t*-test. There is no statistically significant difference.

horizontal growth of the maxilla, a decrease in the inclination of the mandibular plane, and a decrease in the gonial angle in the MB group when compared with the NB.

Discussion

The effect of chronic respiratory obstruction on craniofacial development has been largely studied, but the literature accomplishes articles with a very broad age interval and with controversial results. Thus, it was decided to study a very specific age group with children before the first craniofacial growth spurt and the effect of the change in the mode of breathing on their facial morphology.

Before surgery, the preschool MB presented a significant higher vertical inclination of the mandible, which reveals a posterior mandible rotation when compared with nasal breathers. Bresolin *et al.*[12] and Lessa *et al.*[13] observed the same relation between the MB and the cranial morphology in older children, aged 6 and older. Zucconi *et al.*[14] observed the same alteration in the mandible plane and a predominant vertical growth in children with obstructive sleep apnoea. Moreover, Zettergren-Wijk *et al.*[8] and Kawashima *et al.*[15] also compared mouth breathers with nasal ones and observed changes in the mandibular plane inclination in MB children, even in case of children younger than 6 years old.

The increased inclination between the ramus and the body of the mandible (ArGo.GoMe) in MB children demonstrates that the mandible inclination is not only postural but also bony and morphological changes that occur even in such a young age group. These findings had already been observed in older MB children by other authors[12,16,17]. Sabatoski *et al.*[18], however, found no statistically

Table 3. **Comparison of the cephalometric measurements obtained between times T1 and T2 for the MB and NB groups through paired *t*-test.**

	Group MB					Group NB				
	Initial – T1		Final – T2			Initial – T1		Final – T2		
Measurements	Average	SD	Average	SD	*P*	Average	SD	Average	SD	*P*
SNA (°)	81.6	3.87	82.5	3.8	0.02	82.8	4.6	82.2	4.5	ns
SNB (°)	75.8	2.8	76.6	3.1	ns	77.7	5.1	77.6	4.2	ns
ANB (°)	5.8	2.3	6.0	2.2	ns	5.4	1.7	4.8	1.9	ns
Sn-GoGn (°)	41.2	4.8	38.8	5.1	<0.0001	36.6	4.8	36.6	5.3	ns
SN-PP (°)	6.1	3.1	6.3	3.5	ns	6.0	3.8	6.4	3.3	ns
PP-MP (°)	37.2	4.2	34.5	4.4	<0.0001	32.7	6.0	32.1	6.1	ns
ArGo-GoMe (°)	136.9	3.6	133.4	3.6	<0.0001	131.3	3.2	134.2	5.4	0.02
SN-Gn (°)	70.8	3.5	69.6	3.5	0.0031	69.2	4.8	69.1	5.2	ns
BaN-PtGn (°)	84.2	3.9	86.0	3.9	<0.0001	88.2	3.2	89.0	3.0	ns
N-Me (mm)	100.1	5.2	105.6	5.1	<0.0001	99.0	4.8	105.5	5.5	<0.0001
N-ANS (mm)	43.1	2.9	46.4	3.1	<0.0001	43.1	2.8	46.7	2.7	<0.0001
ANS-Me (mm)	60.1	3.8	62.2	3.3	<0.0001	59.2	3.5	61.4	4.1	0.0004
S-Go (mm)	58.2	3.3	63.0	3.5	<0.0001	60.4	4.4	64.1	5.8	<0.0001
S-Ar (mm)	27.4	2.8	29.9	2.3	<0.0001	28.2	3.4	30.5	2.9	<0.0001
Ar-Go (mm)	33.3	2.7	35.9	3.0	<0.0001	35.8	4.4	37.5	4.6	0.010

ns, nonsignificant; SD, standard deviation; MB, mouth breathing; NB, nasal breathing.

Table 4. Comparison of the variation in the cephalometric measurements (T2 – T1) between the MB and NB groups by Student's *t*-test.

Measurement	T2 – T1 (Group MB)		T2 – T1 (Group NB)		
	Average	SD	Average	SD	*P*
SNA (°)	0.9	2.1	–0.6	1.4	0.005
SNB (°)	0.8	2.2	–0.1	1.9	ns
ANB (°)	0.2	1.8	–0.7	1.9	ns
Sn-GoGn (°)	–2.3	2.6	0.0	3.0	0.004
SN-PP (°)	0.3	2.0	0.4	2.4	ns
PP-MP (°)	–2.7	2.6	–0.5	3.6	0.005
ArGo-GoMe (°)	–3.5	2.6	2.9	5.4	<0.0001
SN-Gn (°)	–1.2	2.1	–0.1	1.9	ns
BaN-PtGn (°)	1.9	2.3	0.8	2.1	ns
N-Me (mm)	5.5	2.8	6.5	3.6	ns
N-ANS (mm)	3.3	1.6	3.5	2.0	ns
ANS-Me (mm)	2.1	2.1	2.2	2.4	ns
S-Go (mm)	4.9	2.7	3.7	2.9	ns
S-Ar (mm)	2.5	2.1	2.3	1.7	ns
Ar-Go (mm)	2.6	3.2	1.7	2.8	ns

ns, nonsignificant; SD, standard deviation; MB, mouth breathing; NB, nasal breathing.

significant difference between mouth and nasal breathers in terms of gonial angle and mandibular plane inclination.

Concerning to the linear measures, MB individuals presented lower average values for the vertical posterior measurements before surgery, which is in accordance with study by Lessa *et al.*[13] and Zucconi *et al.*[14], even in case of children aged 6 or less. The high values of the craniomandibular angle, the angle between the occlusal and mandibular plane, and a vertical reduction in the posterior facial height revealed a posterior rotation of the mandible in MB[14]. On the other hand, Bresolin *et al.*[12] did not find alterations in the posterior facial height in the MB patients.

It was observed a predominant dolichofacial pattern in the MB group before surgery, whereas nasal breathers tend to the mesofacial pattern. These results are in agreement with those reported by other authors[1,10,19] who stated that mouth breathers present the dolichofacial pattern even in very young children, whereas the majority of the nasal breathers are mesofacial.

MB and NB groups were statistically different only for the BaN.PtGn measurement 28 months on average following surgery procedure. It demonstrates a predominant dolichofacial pattern in the mouth breathers even after the rehabilitation of the respiratory pattern. Nevertheless, all other cephalometric differences, previously detected at T1, were compensated after the MB group surgery.

Kerr *et al.*[20] reported that the angular differences observed between the MB and the control groups tended to normality 5 years after adenoidectomy, in children aged between 8 and 13. In this study, mouth breathers became less dolichocephalic in respect of the general face features. Alterations in the mode of breathing following adenotonsillectomy also influenced the position of the mandible, which resulted in a forward rotation of the mandible and a decrease in its inclination in relation to the cranial base and the palatal plane. The mandibular ramus height and posterior facial height showed the greatest proportional increase[21].

The decreased posterior facial height in mouth breathers was significantly corrected after surgery. The anterior facial height was similar between mouth and nasal breathers, both before and after surgery. The growth that occurred in this period was statistically similar for both groups. Many studies have reported a significant correlation between nasal resistance and an increase in the anterior facial height[12,18,22] in children older than 6 years, especially in the inferior anterior region[13]. Kerr *et al.*[20] and Hartgerink and Vig[23], however, did not find any relationship between the nasal resistance and the facial height, neither before nor 5 years after adenoidectomy.

The discrepancy of the cephalometric measurements during the study period revealed that the MB group decreased the mandible plane inclination, which turned its growth direction more horizontal and tended to a mesocephalic facial pattern, which approaches the values found in the NB group. These results show that if the breathing pattern is normalized at an early age, the facial growth responds to normality. This finding is in accordance with some reports[5,6,8,24,25], in which the authors have observed that the mandible presents a more horizontal growth direction after adenoidectomy.

Maxilla and mandible anteroposterior plane increase was very similar between the MB and the NB groups at T1 and T2, compared with cranial base. The literature has brought many controversial results in this respect, in which either maxilla prognathism[26] or retrognathism[7,12,27] is reported in children older than 6 years. In general, the airway surgery did not lead to any change in the maxilla and mandible horizontal growth, although there are other studies[8,28] that agreed with our findings.

According to what had been mentioned, it is important to highlight that older patients present more significant changes in face morphology, occlusal features, and facial pattern. In a younger group, aged 6 or less, there are fewer differences between the facial patterns of mouth-breathing and NB children. The most evident alteration lies on higher inclination of the mandible, predominance of dolichofacial pattern, shortened posterior face, and ramus mandibular height.

Two years postoperatively, all cephalometric measurements that were initially altered, especially in respect to the mandible, tended to normalize when compared with the control group, although there was still a tendency towards the dolichofacial pattern. In other studies, it was pointed out that older children who had their mode of breathing changed through adenoidectomy or tonsillectomy had a limited normalization of the muscular function and functional facial alterations. In this active growth period, harmful consequences can be overcome by changing the breathing pattern, and as Hultcrantz *et al.*[4] stated, patients submitted to airway relief at an earlier age, before the first facial growth spurt, have a more positive prognosis.

Many factors can contribute for the continuity of mouth breathing, such as allergic rhinitis, a recurrent pharyngeal tonsil hypertrophy, and the persistence of the mouth breathing. The great difference in this study was the periodic evaluation by an otorhinolaryngologic doctor during all the analysed period, which confirms that the studied group had maintained NB after surgery. Those children who persisted with mouth breathing, whatever the cause was, were excluded.

Another factor to be considered is the age at which the surgical intervention should be performed. In our study, surgery was carried out around 3 or 4 years of age with excellent results concerning to the skeletal features. The normal growth pattern was regained by these mouth-breathing patients who were submitted to the surgical removal of palatine and/or pharyngeal tonsils. It would be, however, interesting to evaluate whether children, after 6 years old, submitted to a later surgical intervention could have the same benefit as in this age group.

Conclusion

Before surgery, the mouth breathers presented a larger inclination of the mandible plane in relation to the cranial base and palatal plane, a more obtuse gonial angle, a decreased posterior facial height, and a predominant dolichofacial pattern when compared with nasal breathers. After surgery, 3- to 6-year-old children still persisted with dolichofacial pattern when compared with nasal breathers, even though there was a significant normalization in the growth direction of the MB group, a decrease in the inclination of the mandibular plane and in the gonial angle, and an increase in the posterior facial height. The difference between the studied groups reached a significant similarity after respiratory correction on 28 months average.

What this paper adds

- The paper provides information about the skeletal alterations that can happen in MB children between 3 and 6 years old.
- It also points out the importance of an early treatment in the nasal obstruction that leads to mouth breathing.
- After the improvement in the mode of breathing, there is a positive and spontaneous response of the skeletal pattern in children between 3 and 6 years old.

Why this paper is important to paediatric dentists

- The paper points out that paediatric dentists should recognize the importance to early diagnosis and indicate the MB children for a otorhinolaringologist treatment.
- It highlights the alterations that the MB can cause in the children's face growth even at an early age.
- It can be verified in this paper that if the breathing pattern is early modified through an otorhinolaringologist treatment, most of the skeletal alterations can be spontaneous corrected.

References

1 Klein JC. Nasal respiratory function and craniofacial growth. *Arch Otolaryngol Head Neck Surg* 1986; **112**(8): 843–849.

2 Motonaga SM, Berte LC, Anselmo-Lima WT. Respiração bucal: causas e alterações no sistema estomatognático. *Braz J Otorhinolaryngol* 2000; **66**(4): 373–379.

3 Cuccia AM, Lotti M, Caradonna D. Oral breathing and head posture. *Angle Orthod* 2008; **78**(1): 77–82.

4 Hulcrantz E, Larson M, Hellquist R *et al.* The influence of tonsillar obstruction and tonsillectomy on facial growth and dental arch morphology. *Int J Pediatr Otorhinolaryngol* 1991; **22**(2): 125–134.

5 Behlfelt K, Linder-Aronson S, Neander P. Posture of head, the hyoid bone and tongue in children with and without enlarged tonsils. *Eur J Orthod* 1990; **12**: 458–467.

6 Agren K, Nordlander B, Linder-Aronson S *et al.* Children with nocturnal upper airway obstruction: postoperative orthodontic and respiratory improvement. *Acta Otolaryngol* 1998; **118**: 581–587.

7 Linder-Aronson S. Respiratory function in relation to facial morphology and dentition. *Br J Orthod* 1979; **6**(2): 59–71.

8 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**: 319–326.

9 Valera FCP, Trawitzki LVV, Anselmo-Lima WT. Myofunctional evaluation after surgery for tonsils hypertrophy and its correlation to breathing pattern: a 2 years-follow up. *Int J Pediatr Otorhinolaryngol* 2006; **70**: 221–225.

10 Brodsky L, Koch JR. Anatomic correlates of normal and diseased adenoids in children. *Laryngoscope* 1992; **102**(11): 1268–1274.

11 Cohen D, Konak S. The evaluation of radiographs of the nasopharynx. *Clin Otolaryngol* 1985; **10**(2): 73–78.

12 Bresolin D, Shapiro PA, Shapiro GG *et al.* Mouth breathing in allergic children: It's relationship to dentofacial development. *Am J Orthod* 1983; **83**(4): 334–339.

13 Lessa FCR, Enoki C, Feres MFN *et al.* Influência do padrão respiratório na morfologia craniofacial. *Braz J Otorhinolaryngol* 2005; **71**(2): 156–160.

14 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**: 411–417.

15 Kawashima S, Peltomäki T, Sakata H *et al.* Craniofacial morphology in preschool children with sleep-related breathing disorder and hypertrophy of tonsils. *Acta Paediatr* 2002; **91**: 71–77.

16 Ricketts RM. Respiratory obstruction syndrome. *Am J Orthod* 1968; **54**(7): 495–507.

17 Bresolin D, Shapiro GG, Shapiro PA *et al.* Facial characteristics of children who breathe through the mouth. *Pediatrics* 1984; **73**(5): 622–625.

18 Sabatoski CV, Maruo H, Camargo ES *et al.* Estudo comparativo de dimensões craniofaciais verticais e horizontais entre crianças respiradoras bucais e nasais. *J Bras Ortodon Ortop Facial* 2002; **7**(39): 246–257.

19 Tourné LPM. Growth of the pharynx and its physiologic implications. *Am J Orthod Dentofacial Orthop* 1991; **99**(2): 129–139.

20 Kerr WJS, McWilliam JS, Linder-Aronson S. Mandibular form and position related to changed mode of breathing – a five-year longitudinal study. *Angle Orthod* 1989; **59**: 91–96.

21 Peltomäki T. The effect of mode of breathing on craniofacial growth-revisited. *Eur J Orthod* 2007; **29**(5): 426–429.

22 Trask GM, Shapiro PA. The effect of perennial allergic rhinitis on dental and skeletal development: a comparison of sibling pairs. *Am J Orthod Dentofac Orthop* 1987; **92**(4): 286–293.

23 Hartgerink DV, Vig PS. Lower anterior facial height and lip incompetence do not predict nasal airway obstruction. *Angle Orthod* 1989; **59**(1): 17–23.

24 Linder-Aronson S, Woodside DG, Lundströn A. Mandibular growth direction following adenoidectomy. *Am J Orthod* 1986; **89**(4): 273–284.

25 Arun T, Isik F, Sayinsu K. Vertical growth changes after adenoidectomy. *Angle Orthod* 2003; **73**(2): 146–150.

26 Trotman CA, Macnamara JA Jr, Dibbetts JMH *et al.* Association of lip posture and dimensions of the tonsils and sagittal airway with facial morphology. *Angle Orthod* 1997; **67**(6): 425–432.

27 Kluemper GT, Vig PS, Vig KWL. Nasorespiratory characteristics and craniofacial morphology. *Eur J Orthod* 1995; **17**: 491–495.

28 Woodside DG, Linder-Aronson S, Lundstrom A *et al.* Mandibular and maxillary growth after changed mode of breathing. *Am J Dentofacial Orthop* 1991; **100**(1): 1–18.