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Treatment and post-treatment effects of facemask therapy on the sagittal pharyngeal dimensions in Class III subjects

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SUMMARY The purpose of this cephalometric study was to analyse the treatment and post-treatment craniofacial effects of a facemask (FM) combined with a bite block (BB) with specific regard to the sagittal pharyngeal dimensions in subjects with a Class III malocclusion when compared with an untreated Class III control group. The FM/BB group (22 subjects, 12 females and 10 males) had a mean age pre-treatment (T1) of 8.9 ± 1.5 years, at the end of active treatment (T2) of 10.5 ± 1.3 years, and post-treatment (T3) of 12.6 ± 1.9 years. The treated group was compared with a control group of 14 subjects (6 females and 8 males) with untreated Class III malocclusions that matched the FM/BB group as to age at T1, T2, and T3, observation periods and skeletal maturation. Comparisons of the T2–T1 and T3–T1 changes between the two groups were analysed with the Mann–Whitney test.

Significant favourable skeletal changes in the maxilla and mandible were observed in the treated group both after Ts2 and T3. No significant short- or long-term changes in the sagittal oropharyngeal and nasopharyngeal airway dimensions were induced by maxillary protraction in subjects with a Class III malocclusion when compared with untreated controls.

Introduction

Orthopaedic treatment of a Class III malocclusion with a facemask (FM) is able to produce favourable changes in growing subjects by both enhancement of maxillary growth and restraint and/or redirection of mandibular growth (De Toffol *et al.*, 2008). The use of lateral cephalograms appears adequate for the investigation of sagittal changes in the pharyngeal dimensions (Hiyama *et al.*, 2002; Sayinsu *et al.*, 2006; Kilinç *et al.*, 2008; Oktay and Ulukaya, 2008).

While some authors (Sayinsu *et al.*, 2006; Kilinç *et al.*, 2008) used a FM in combination with rapid maxillary expansion, Hiyama *et al.* (2002) and Oktay and Ulukaya (2008) treated Class III patients by means of maxillary protraction only. Significant changes of both oropharyngeal and nasopharyngeal dimensions have been reported following FM therapy (Kilinç *et al.*, 2008; Oktay and Ulukaya, 2008), while Hiyama *et al.* (2002) did not assess changes in the airway dimensions and Sayinsu *et al.* (2006) found significant changes only for nasopharyngeal size. The major limitation of all these studies is the lack of untreated controls with Class III malocclusions (with one exception; Kilinç *et al.*, 2008) and the short-term nature of the observations.

The aim of the present study was to evaluate the craniofacial changes induced by a FM combined with a bite block (BB) with special regard to the oro- and nasopharyngeal sagittal airway dimensions in subjects with dentoskeletal Class III malocclusions when compared with an untreated Class III control group immediately after therapy and at post-treatment observation.

Subjects and methods

Subjects

The treated group comprised 22 subjects (12 females and 10 males) with a Class III malocclusion, who were treated consecutively with an FM combined with a lower removable BB appliance by a single operator (PC) at the Department of Orthodontics, University of Rome 'Tor Vergata'. Lateral cephalograms were taken before treatment (T1), at the end of active treatment (T2), and at an average interval after the completion of FM/BB therapy of approximately 2 years (about 42 months after the initiation of treatment; T3). The average age of the FM/BB group was 8.9 ± 1.5 years at T1, 10.5 ± 1.3 years at T2, and 12.6 ± 1.9 years at T3. At T1, all patients had a Class III malocclusion in the mixed dentition characterized by Wits appraisal of −2 mm or less, an anterior crossbite or incisor end-to-end relationship, and a Class III molar relationship.

The patients were instructed to wear the FM at least 14 hours per day. The FM was attached to a double-arch structure cemented to the upper first molars. Forces of 600 g were used during protraction therapy. Cooperation was good for all patients. During FM treatment, a removable BB appliance was used full-time. The BB appliance was constructed in the form of a Schwarz plate for the lower arch with a vestibular arch, occlusal resin splints, and an expansion screw that was activated when needed. The splints were used to control molar eruption, limit intermaxillary divergence, and prevent clockwise mandibular rotation. The patients were instructed to wear the BB 24 hours a day, including during meals; cooperation was good for all subjects.

All patients were treated at least to a positive dental overjet before discontinuing treatment; most patients were overcorrected towards a Class II occlusal relationship (Westwood *et al.*, 2003). The T1−T2 interval comprised active therapy followed by 6–9 months with a Hawley retainer in the maxillary arch, whereas no appliance was worn during the post-treatment period (T2−T3).

The treated group was compared with an untreated group of 14 subjects (6 females and 8 males) with a Class III malocclusion selected from the records at the Department of Orthodontics, University of Florence. The average age was 7.6 ± 1.4 years at T1, 9.8 ± 1.9 years at T2, and 11.9 ± 1.2 years at T3. All the treated and control subjects showed a prepubertal stage of skeletal growth (CS 1; Baccetti *et al.*, 2005) at T1 and a post-pubertal stage (CS 4, CS 5, or CS 6) at T3.

Cephalometric analysis

A customized digitization regimen and analysis were used for all cephalograms examined in this study. Before the cephalometric analysis, the intraobserver measurement error was evaluated. Fifteen lateral cephalograms, selected from various subjects in the study, were traced and measured twice within a week by the same operator (MM). The measurements at both times for each patient were analysed with the intraclass coefficient correlation, which varied between 0.966 and 0.995. These values indicated a high level of intraobserver agreement. Lateral cephalograms for each subject in both the treatment and the control groups at T1, T2, and T3 were taken using a standardized radiographic protocol, with an 8 per cent magnification factor.

Cephalograms were traced for each subject at the three time points, and the following variables were measured:

1. Cranial flexure: NSBa angle;
2. Maxillary skeletal: A to nasion perp (point A to a line drawn perpendicular to Frankfort horizontal from nasion), Co–A;
3. Mandibular skeletal: Pg to nasion perp (point Pg to a line drawn perpendicular to Frankfort horizontal from nasion), Co–Go, Co–Gn;
4. Sagittal skeletal: Wits appraisal (distance between the two points of intersection of the two perpendicular lines from points A and B to the functional occlusal plane) and maxillo–mandibular difference (difference between Co–Gn and Co–A);
5. Vertical skeletal: palatal plane to mandibular plane angle, gonial angle (Ar–Go–Me angle).

Specific variables to evaluate the sagittal nasopharyngeal and oropharyngeal airway dimensions were chosen according to the definitions of McNamara (1984) and Martin *et al.* (2006; Figure 1).

The method error for all the cephalometric variables assessed on 20 sets of repeated measurements was calculated by means of Dahlberg's (1940) formula. The error for linear measurements ranged from 0.1 to 0.3 mm, while for angular measurements it varied by 0.2–0.4 degrees.

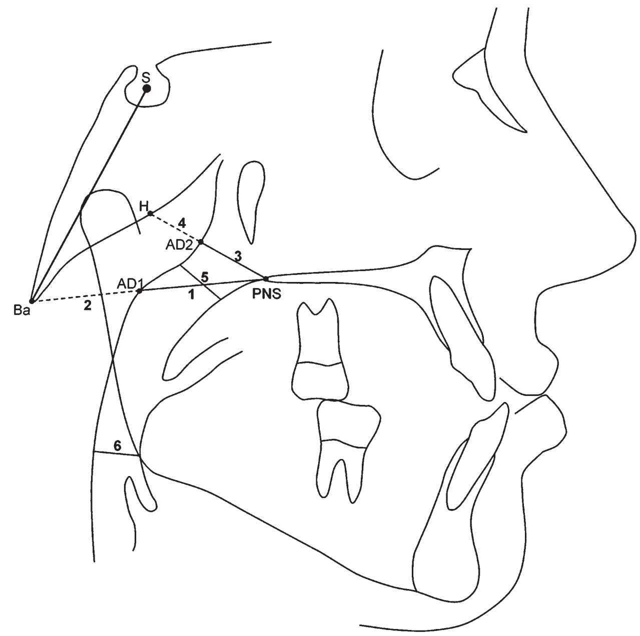

Figure 1 Cephalometric measurements for the analysis of airway dimensions. (1) PNS-AD1: lower airway thickness; distance between the PNS and the nearest adenoid tissue measured through the PNS-Ba line (AD1). (2) AD1-Ba: lower adenoid thickness; defined as the soft tissue thickness at the posterior nasopharynx wall through the PNS-Ba line. (3) PNS-AD2: upper airway thickness; distance between the PNS and the nearest adenoid tissue measured through a perpendicular line to S–Ba from PNS (AD2). (4) AD2-H: upper adenoid thickness; defined as the soft tissue thickness at the posterior nasopharynx wall through the PNS-H line (H, Hormion, point located at the intersection between the perpendicular line to S–Ba from PNS and the cranial base). (5) McNamara's upper pharynx dimension: the minimum distance between the upper soft palate and the nearest point on the posterior pharynx wall. (6) McNamara's lower pharynx dimension: the minimum distance between the point where the posterior tongue contour crosses the mandible and the nearest point on the posterior pharynx wall.

Statistical analysis

Descriptive statistics were calculated for all the cephalometric measurements in the two groups at T1, for the T2−T1 changes (active treatment changes) and for the T3−T1 changes (treatment and post-treatment changes). The preliminary assessment of sample size revealed that with the number of subjects included in the two groups, the power of the study exceeded 0.80. Shapiro Wilks' test revealed a lack of normal distribution for the data. The following comparisons were, therefore, performed by means of Mann–Whitney tests: comparison of craniofacial starting forms at T1, between the T2−T1 and T3−T1 changes between the treated and the control groups.

Logistic regression on the variables at T1 with T3−T1 change of the upper pharynx as the dependent variable was performed with the aim of identifying T1 predictive variables for individual response to treatment in terms of modification of airway size (method stepwise, with P to enter <0.05 and

P to remove >0.1). All statistical computations were performed with a statistical software (MedCalc 9.6.2.0, MedCalc Software, Mariakerke, Belgium).

Results

No significant differences between the treated and the control groups at T1 were found for any craniofacial variable or airway measurement (Table 1). Descriptive statistics and comparisons of the T2−T1 and T3−T1 changes between treated and untreated control groups are reported in Tables 2 and 3.

During active treatment (T2−T1), the treated group showed significant increments in maxillary skeletal variables, as well as significant improvements in the Wits appraisal and in the Max/Mand difference. A significant increase in the vertical intermaxillary relationships was also found. No statistically significant differences were observed for any of the analysed variables for upper and lower sagittal airway dimensions.

During the overall treatment and post-treatment period (T3−T1), the treated group exhibited a significant increase in A to nasion perp and a significant reduction in mandibular length (Co–Gn). Significant improvements in the Wits appraisal and in the Max/Mand difference were still present. No statistically significant differences were found for the vertical skeletal relationships or for the upper and lower sagittal airway dimensions.

Logistic regression with the T3−T1 change in upper pharynx as the dependent variable (greater than 4.8 mm versus less than 4.8 mm, as 4.8 mm is the average difference in T3−T1 change between treated and control groups, Table 3) on the variables at T1 did not reveal any predictive variable.

Discussion

The present study evaluated the treatment and post-treatment craniofacial changes produced by orthopaedic therapy of Class III malocclusions by means of an FM/BB protocol with special regard to the sagittal oropharyngeal and nasopharyngeal airway dimensions. The literature reports contrasting findings with regard to the possibility of improving the sagittal airway dimension by means of maxillary protraction (Hiyama *et al.*, 2002; Sayinsu *et al.*, 2006; Kilinç *et al.*, 2008; Oktay and Ulukaya, 2008).

The features of the present investigation were represented by:

1. The study evaluated both active and post-treatment outcomes, with the post-treatment observation approximately 2 years after the completion of FM/BB therapy; during the post-treatment period, the patients did not wear any orthodontic appliance.
2. A group of 14 subjects with untreated Class III malocclusions was used as a longitudinal control sample for both active treatment and post-treatment periods.
3. All subjects in both treated and control groups were at a prepubertal stage in skeletal development at initial observation and at post-pubertal stage at the final observation.

Table 1 Descriptive statistics and comparison of starting forms.

Cephalometric measures	Treated group $N = 22$		Control group $N = 14$		Difference	Significant
	Mean	SD	Mean	SD		
Cranial flexure						
NSBa (°)	128.4	5.1	128.0	5.4	0.4	NS
Maxillary skeletal						
A to nasion perpendicular (mm)	−0.8	2.7	−1.3	3.3	0.5	NS
Co–A (mm)	75.2	5.0	74.6	2.8	0.6	NS
Mandibular skeletal						
Pg to nasion perpendicular (mm)	−3.1	5.1	−4.9	5.6	1.8	NS
Co–Gn (mm)	99.7	5.3	98.8	5.3	0.9	NS
Co–Go (mm)	45.3	4.1	45.9	3.2	−0.6	NS
Skeletal difference						
Wits (mm)	−6.2	2.6	−7.2	4.1	1.4	NS
Max/Mand difference (mm)	24.5	2.6	24.1	3.7	0.4	NS
Vertical skeletal						
Palatal plane to mandibular plane (°)	29.6	6.4	30.5	4.0	−0.9	NS
Gonial angle (°)	134.1	6.3	135.5	4.4	−1.4	NS
Airway dimensions						
PNS-AD1 (mm)	20.2	3.2	19.1	4.0	1.1	NS
AD1-Ba (mm)	22.2	4.7	21.3	4.7	0.9	NS
PNS-AD2 (mm)	14.6	2.0	13.1	3.1	1.5	NS
AD2-H (mm)	15.8	3.0	15.1	3.4	0.7	NS
Upper pharynx (mm)	9.8	3.1	9.8	3.3	0.0	NS
Lower pharynx (mm)	15.4	3.3	14.0	4.1	1.4	NS

NS, not significant.

Table 2 Descriptive statistics and comparison of the pre-treatment and end of active treatment (T_1-T_2) changes between the treated and control group.

Cephalometric measures	Treated group $N = 22$		Control group $N = 14$		Difference	Significant
	Mean	SD	Mean	SD		
Cranial flexure						
NSBa (°)	−0.6	3.1	0.5	4.4	−1.1	NS
Maxillary skeletal						
A to nasion perpendicular (mm)	1.3	3.0	−1.2	2.0	2.5	**
Co–A (mm)	5.2	3.9	2.1	2.7	3.1	*
Mandibular skeletal						
Pg to nasion perpendicular (mm)	−1.3	6.1	0.2	4.3	−1.5	NS
Co–Gn (mm)	5.1	4.3	6.2	5.2	−1.1	NS
Co–Go (mm)	2.3	3.1	3.5	3.3	−1.2	NS
Maxillary/mandibular						
Wits (mm)	1.8	3.2	−0.7	3.8	2.5	*
Max/Mand difference (mm)	−0.2	2.2	4.1	3.5	−4.3	**
Vertical skeletal						
Palatal plane to mandibular plane (°)	2.1	2.2	−0.6	1.7	2.7	**
Gonial angle (°)	−0.2	3.9	−1.2	3.4	1.0	NS
Airway dimensions						
PNS-AD1 (mm)	2.8	3.2	3.5	4.7	−0.7	NS
AD1-Ba (mm)	−0.4	2.9	−1.8	4.8	1.4	NS
PNS-AD2 (mm)	3.2	2.8	1.8	3.2	1.4	NS
AD2-H (mm)	0.3	2.4	−0.9	2.2	1.2	NS
Upper pharynx (mm)	2.0	2.7	2.4	3.8	−0.4	NS
Lower pharynx (mm)	0.0	3.5	2.1	5.3	−2.1	NS

NS, not significant. *$P < 0.05$, **$P < 0.01$.

Table 3 Descriptive statistics and comparison of the pre- and post-treatment (T_1-T_3) changes between the treated and control group.

Cephalometric measures	Treated group $N = 22$		Control group $N = 14$		Difference	Significant
	Mean	SD	Mean	SD		
Cranial flexure						
NSBa (°)	0.0	2.3	−1.2	3.1	1.2	NS
Maxillary skeletal						
A to nasion perpendicular (mm)	1.0	3.1	−1.1	2.1	2.1	*
Co–A (mm)	6.7	4.8	4.8	4.1	1.9	NS
Mandibular skeletal						
Pg to nasion perpendicular (mm)	0.9	5.0	2.9	5.1	−2.0	NS
Co–Gn (mm)	9.5	5.4	12.2	5.7	−2.7	*
Co–Go (mm)	4.7	5.3	6.3	4.2	−1.6	NS
Maxillary/mandibular						
WITS (mm)	2.0	3.0	−0.2	3.0	2.2	*
Max/Mand difference (mm)	2.8	3.0	7.4	4.4	−4.6	**
Vertical skeletal						
Palatal plane to mandibular plane plane (°)	0.5	2.3	−0.6	3.3	1.1	NS
Gonial angle (°)	−1.0	4.2	0.4	3.7	−1.4	NS
Airway dimensions						
PNS-AD1 (mm)	5.1	3.1	2.3	6.2	2.8	NS
AD1-Ba (mm)	−1.6	2.6	−0.3	5.6	−1.3	NS
PNS-AD2 (mm)	5.6	2.5	3.6	5.2	2.0	NS
AD2-H (mm)	−1.0	3.7	−1.6	4.1	0.6	NS
Upper pharynx (mm)	4.8	3.1	3.2	5.0	1.6	NS
Lower pharynx (mm)	−0.1	3.8	0.2	3.9	−0.3	NS

NS, not significant. *$P < 0.05$, ** = $P < 0.01$.

The results of the present investigation showed significant favourable effects of FM therapy on the skeletal components of Class III malocclusion, which were limited to the maxilla (2.5 mm improvement for A to nasion perp and 3.1 mm improvement for Co–A) during the active treatment period and were extended to the mandible as well during the overall treatment and post-treatment period (2.7 mm of reduction in the growth of the mandible along Co–Gn). These changes led to favourable outcomes for both the Wits appraisal (2.2 mm improvement over the controls in the long-term) and the Max/Mand difference (4.6 mm improvement over the controls in the long term). The significant increase in the vertical intermaxillary relationship during the active treatment period (2.7 degrees over the controls) was not present in the long term. It should also be noted that for the majority of craniofacial variables, the standard deviations were rather large compared with the mean changes, thus reflecting a wide range of interindividual variability.

In spite of the favourable skeletal changes in the maxillary bony structures, no significant differences between the treated and control group were observed for any sagittal airway dimension variable. These findings differ from those by Kilinç *et al.* (2008) and Oktay and Ulukaya (2008), who reported that maxillary protraction with (Kilinç *et al.*, 2008) or without (Oktay and Ulukaya, 2008) rapid maxillary expansion induced statistically significant increments in the airway dimensions. It should be emphasized that both these studies were short term in design and that the study of Oktay and Ulukaya (2008) did not include a Class III control group.

Logistic regression was carried out on the variables at T1 with the T3−T1 change in upper pharynx as the dependent variable (greater than 4.8 mm versus less than 4.8 mm, as 4.8 mm was the average difference in T3−T1 change between treated and control groups). This analysis was undertaken because of the great variability in the changes of the airway measurements that suggested the need for identification of better responders to treatment. Statistical evaluation did not reveal any pre-treatment predictive variable for individual changes in the pharyngeal dimension.

In the appraisal of the lack of significant treatment-induced airway modifications, the physiological changes in the lymphoid tissue on the posterior pharyngeal wall should also be considered. Handelman and Osborne (1976) reported that during the pre-school years, the adenoid area increases more than the bony nasopharyngeal area, resulting in a restriction of airway space. Linder-Aronson and Leighton (1983) analysed the development of the posterior nasopharyngeal wall between 3 and 16 years and found that the size of the soft tissue was greater at 5 years; thereafter, a decrease occurred from 6 to 10 years. In agreement with this physiological growth pattern of the oronasal lymphoid tissue. The results of the present study revealed a decrease of the lymphoid tissue on the posterior pharyngeal wall (AD1-Ba and AD2-H) both in the treated and control group during the overall observation period. Even when considering this decrease of pharyngeal lymphoid tissue between 7 and 10 years (an interval in age similar to the one in the present study), therapeutic intervention with maxillary protraction was not able to produce a significant increase in the airway dimensions.

Conclusions

The findings of the present study demonstrated the followings:

1. The FM/BB protocol produced significant favourable changes both in the maxillary and mandibular structures in Class III subjects when compared with untreated controls; these favourable changes were maintained at the post-treatment observation after puberty.
2. No significant changes for the oro- and nasopharyngeal sagittal airway dimensions were induced by FM/BB therapy when compared with untreated Class III subjects.

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