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RESEARCH ARTICLE

Effects of facemask therapy in the treatment of skeletal class III malocclusion in Vietnamese children

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ABSTRACT

Sparse data are available on the effects of facemask therapy in treatment of skeletal class III malocclusion in Vietnamese children. The purpose of this study was to investigate the skeletal, dental, and soft-tissue profile changes following facemask treatment in children with skeletal class III malocclusion. Twenty-four children (7-12 years-old) with skeletal class III malocclusion treated with facemask appliance were included in this study. All lateral cephalograms taken before and after treatment had been manually traced, followed by cephalometric landmark identification and parameter measurements. Significant skeletal, dental and soft tissue profile changes after treatment were recorded and statistically evaluated by paired t test at a 0.05 significance level. After treatment, the maxilla moved forward (SNA increased 1.53 degrees and A–Y increased 1.93 mm; $p<0.001$). The mandible rotated backwards and downwards (SNB decreased 1.35 degrees; B–Y decreased 1.12mm; $p<0.001$). These movements in the maxilla and mandible caused a significant improvement in intermaxillary sagittal relationship (ANB increased 2.89degrees; the convexity angle increased 4.7 degrees; Wits appraisal increased 3.77mm; $p<0.001$). The maxillary incisors moved forward (4.57 degrees). The improvement in overjet was 5.83 mm. The change in Prn-Y and Ls–E measurement was 2.46mm and 2.72mm, respectively. Our results showed that facemask was highly effective for treating skeletal class III malocclusion and improving facial esthetics. Facemask treatment is a highly effective for skeletal class III malocclusion because it leads to positive changes in the jaws, teeth and soft tissue after 1-year of treatment.

Key words: Facemask**,** skeletal class III malocclusion, Vietnamese children

INTRODUCTION

The skeletal Class III malocclusion is a facial deformity characterized by a protruded position of the mandible in relation to the cranial base or maxilla. The prevalence of class III malocclusion varies among different ethnic groups with the highest prevalence being seen among Asians[1,2]. The skeletal Class III malocclusion might be due to mandibular prognathism, maxillary retrognathism, or a combination of these components. Anterior crossbite and discrepancies of dental or skeletal components in the anteroposterior or vertical directions are the common clinical manifestations of skeletal class III malocclusion. Skeletal Class III malocclusion can be classified into two categories based on patient development: developing and non-developing malocclusions. Early treatment for developing class III malocclusions have been recommended by a number of authors to obtain jaw modification thanks to bone development[3,4,5]. The timing of the early treatment will determine the effectiveness of class III malocclusion treatment. In a long-term follow-up study, Hägg et al. found that early treatment on two thirds of 7-10 year-old patients result in stable positive overjet 8 years after active treatment[6]. Skeletal class III malocclusion patients who are not treated early during growing stage of the jaws will develop more severe skeletal class III growth patterns. This may lead to an increase in the needs of orthodontic surgery in adulthood. Early treatment of skeletal class III malocclusion can reduce orthognathic surgery rates or circumvent orthognathic surgery when the patient is fully grown[7].

Maxillary retrognathia in combination with normal or prognathic mandible accounts for the highest percentage of skeletal class III malocclusion. Approximately 30–40% of Class III patients exhibit some degree of maxillary deficiency[8,9]. The proper treatment for developing class III malocclusion patients with maxillary deficiency is using devices that help to protract the maxilla, with or without expansion[10]. The facemask is the most widely used orthopedic appliance which can anteriorly displace the superior maxilla or stimulate maxillary growth, thus preventing mandibular development. Therefore, facemasks help to decrease jaw discrepancies and may improve patient function and esthetics[11]. This study aims to evaluate the skeletal, dental and soft tissue profile changes following facemask treatment of skeletal class III malocclusion patients, treated in the faculty of Odonto-stomatology, University of Medicine and Pharmacy at Ho Chi Minh city.

MATERIALS AND METHODS:

Study subjects

The study used convenience sampling to enroll 24 children including 7 males (29.2%) and 17 females (70.8%), aged between 7 and 12 years with class III malocclusion, caused by maxillary deficiency, which received orthodontic treatment with a facemask at the Department of Orthodontics, faculty of Odonto-stomatology, University of Medicine and Pharmacy at Ho Chi Minh city, Vietnam from September, 2015 to May, 2018. The inclusion criteria were skeletal class III malocclusion (ANB angle of 0° or less, Wits appraisal of -2mm or less), caused by maxillary retrusion in combination with a normal or mildly prognathic mandible; Angle Class III malocclusion with anterior crossbite; normal mandibular vertical developmental trend (SN-GoGn angle of 40° or less); fully erupted permanent upper first molars and upper central incisors; children's assent and the permission of their parents. Exclusion criteria were any hypodontia, any congenital anomalies associated with cleft lip, and palate and any previous orthodontic treatment. This study was approved by the University of Medicine and Pharmacy at Ho Chi Minh city ethical committee on 15/7/2016, number 215/ĐHYD-HĐ.

Treatment procedures

The research subjects were treated with a facemask combined with anchorage, which is a pallatal expander such as a Hyrax or an acrylic McNamara-type appliance. The elastics extended from the hooks on the maxillary anchorage to the crossbar on the facemask. The direction of elastic traction was forward and downward, creating a 30° angle with the occlusal plane (**Figure 1**). The elastic generates approximately 400-600 grams of force per side. Patients were instructed to activate the palatal expander with a pattern of a 1/2 turn every week. The facemask was used for 12-14 hours a day. The treatment duration began with the placement of the palatal expander appliance and using facemask. It finished after achieving anterior crossbite correction and Angle class I or class II molar relation.

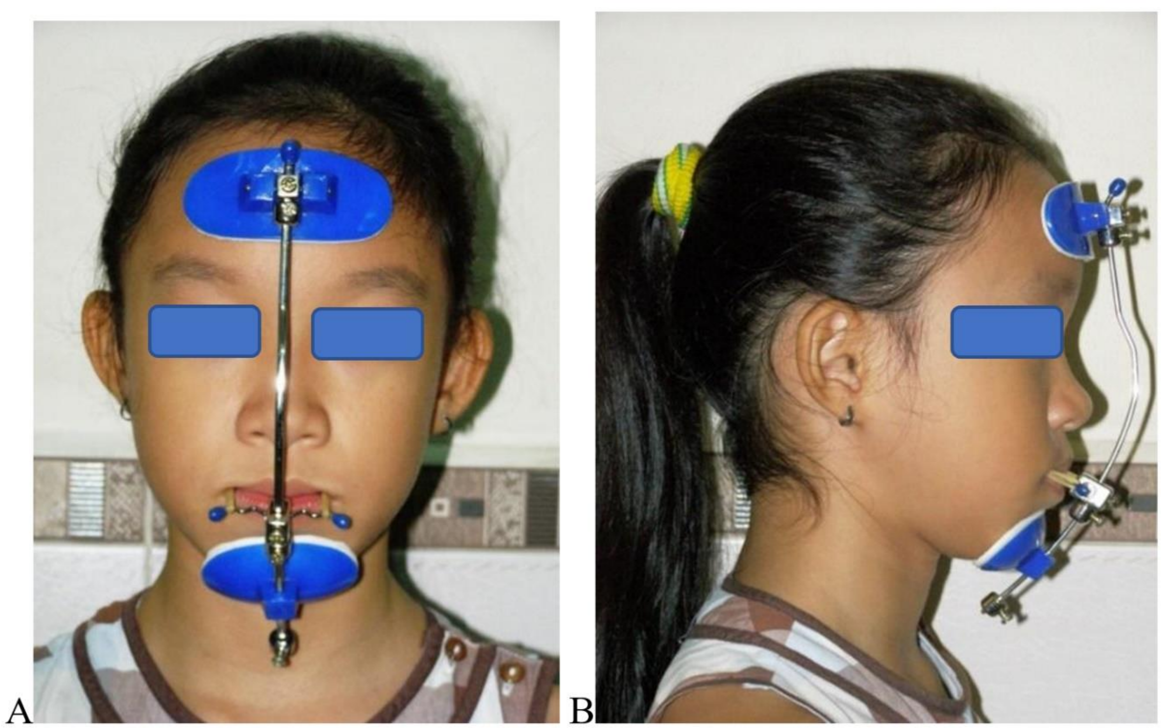

Figure 1: Frontal view (A) and lateral view (B) of patient while using facemask

Cephalometric analysis

All cephalographs were taken in standing position and in the same cephalostat. The patients were requested to keep their teeth in centric occlusion and their lips were at rest. Lateral cephalometric radiographs were taken at the beginning (pre-treatment) and, right after achieving the treatment goals (post-treatment) using ORTHOPHOS XG cephalometer (Sirona, German) by one well trained technician in the department of Radiology, faculty of Odonto-Stomatologh, University of Medicine and Pharmacy. Throughout the research, we always kept the focus-subject and subject-film distances unchanged. Cephalographs must have good quality without any artifacts that could affect with cephalometric landmark identification.

All of the pre-treatment and post-treatment lateral cephalographs of the study subjects were carefully hand-traced by the same observer on 0.003 matte orthodontic tracing paper using 0.5 mm point-size lead pencil. The cephalographs were stabilized on the x-ray film viewer with patient's face looked toward the right-hand side. Aligning the tracing paper on the lateral cephalograph as following steps:

- Draw 3 crosses on 3 different positions of the cephalograph.
- Overlay the sheet of tracing paper on the cephalograph with the smooth side face to the cephalograph and attach the top edge with adhesive tape.
- Trace the crosses onto the tracing paper. Write the patient's name, age and date of radiograph on the top left-hand corner of the paper.
- Identify and trace all the investigating structures and landmarks.

Determination of cephalometric landmarks

All of the cephalometric landmarks used in this study are described as: N: *The most anterior point on the frontonasal suture on the sagittal plane;* S: *The midpoint of the sella turcica;* A: *The deepest point in the concavity between ANS and the upper incisor alveolar crest, on the sagittal plane;* B: *The deepest point in the concavity between pogonion and the lower incisor alveolar crest, on the sagittal plane;* ANS: *The tip of the anterior nasal spine;* Pog: *The most anterior point on the bony chin;* Me: *The lowest point on the bony outline of the mandibular symphysis;* Prn: *The most anterior point on tip of nose;* Ls: *The median point in the upper margin of the upper membranous lip;* Li: *The median point in the lower margin of the lower membranous lip;* U1: *The upper incisal edge point;* U6: *The mesial contact point of the first upper molar;* Pog(s): *Most anterior point on outline of ST chin; and* E: *Esthetic line E extends from Prn to Pog(s).* The coordinate system X Y was choosed for standardization. The X axis ran through S and created an angle of 7° with S-N line as a horizontal reference line. The Y axis ran through S and was perpendicular to the x axis, as a vertical reference line.

Measurements of the skeletal, dental and soft tissue

The skeletal measurements on the cephalograph were determined as:
SNA(º): *Angle formed by the intersection of lines S-N and N-A planes;* A-Y(mm): *Distance from A to y axis;* ANS-Y(mm): *Distance from ANS to y axis;* ANS-Me(mm)*: Height of anterior lower facial, Distance from anterior nasal spine to menton;* SNB(º): *Angle formed by the intersection of lines S-N and N-B planes;* MP/SN(o): *Angle between mandibular plane to S-N plane;* B-Y(mm): *Distance from B to y axis;* Wits appraisal (mm): *The distance from the perpendicular lines from point A and B to the functional occlusal plane;* ANB(º): *Angle formed by the intersection of lines A-N and N-B planes.*

The dental measurements on the cephalograph were determined as:
U1/SN(º): *The angle formed by the upper incisor axis to the SN line;* U1-X(mm): *Distance from the incisal edge of the upper central incisor to the x axis;* U1-Y(mm): *Distance from the incisal edge of the upper central incisor to the y axis;* U6-X(mm): *Distance from the mesial contact point of the first upper molar to the x axis;* U6-Y(mm): *Distance from the mesial contact point of the first upper molar to the y axis;* L1/MP(º): *The angle formed by the lower mandibular incisor to the plane formed by the lower border of the mandible;* Overjet (mm): *The anteroposterior distance between the incisal edge of the upper central incisor and the corresponding reference point on the mandibular incisor;* U1/L1(º): *The angle formed by the upper and lower incisors axis.*

The soft-tissue measurements were determined as:
Prn –Y(mm): *Distance from Prn to the Y axis;* Ls-Y (mm): *Distance from Ls to the Y axis;* Li-Y (mm): *Distance from Li to the Y axis;* Ls-E (mm): *Distance from Ls to the E-line;* Li – E (mm): *Distance from Ls to the E-line;* Nasolabial angle (º): *The angle formed by a line tangent to the base of the nose and a line tangent to the upper lip;* Pog(s)-X (mm): *Distance from Pog(s) to the X axis;* Pog(s) – Y (mm): *Distance from Pog(s) to the X axis.*

A total of 48 cephalograms of 24 research subjects treated with facemask were traced and scanned into the computer. AutoCAD software (Autodesk Inc., San Rafael, CA, USA) was used to measure angles and distances. In AutoCAD, lines were measured in millimeters (mm) and the angles were measured in degrees (º). All measurements were made by one investigator. Five randomly selected radiographs were traced and measured all variables twice by the same investigator, with an interval of at least 2 weeks apart between tracings to help eliminate memory bias. The inter-examiner agreements were greater than 95%.

Statistical analyses

All of the data of the samples were analyzed using SPSS version 21 (SPSS Inc., IL, USA). The statistical analysis included means and standard deviations of the investigating variables on cephalograms prior and after applying the facemask treatment. The paired-samples t-test was used to access the skeletal, dental, and soft-tissue changes. $p<0.05$ was defined to be statistically significant for all tests.

RESULTS

Subjects

There were 24 patients who completed the treatment in this study, including 7 males (29.2%) and 17 females (70.8%). Age distribution was as follows: 18 patients aged 7 to 10 comprise 75% of the total and 6 patients aged 11 to 12 comprise 25% of the total. The mean age of the study participants is 8.81 ± 1.33 years old. The treatment goals were to achieve positive overjet and class I or class II class I or class II molar relation. The treatment time was counted from the first day applying the palatal expander appliance to the day achieving treatment goals. The average treatment time was 12.50 ± 6.5 months (from 5 to 29 months). Facemask treatment definitely improves the patient's profile via significant skeletal, dental and soft tissue changes (**Figure 2**).

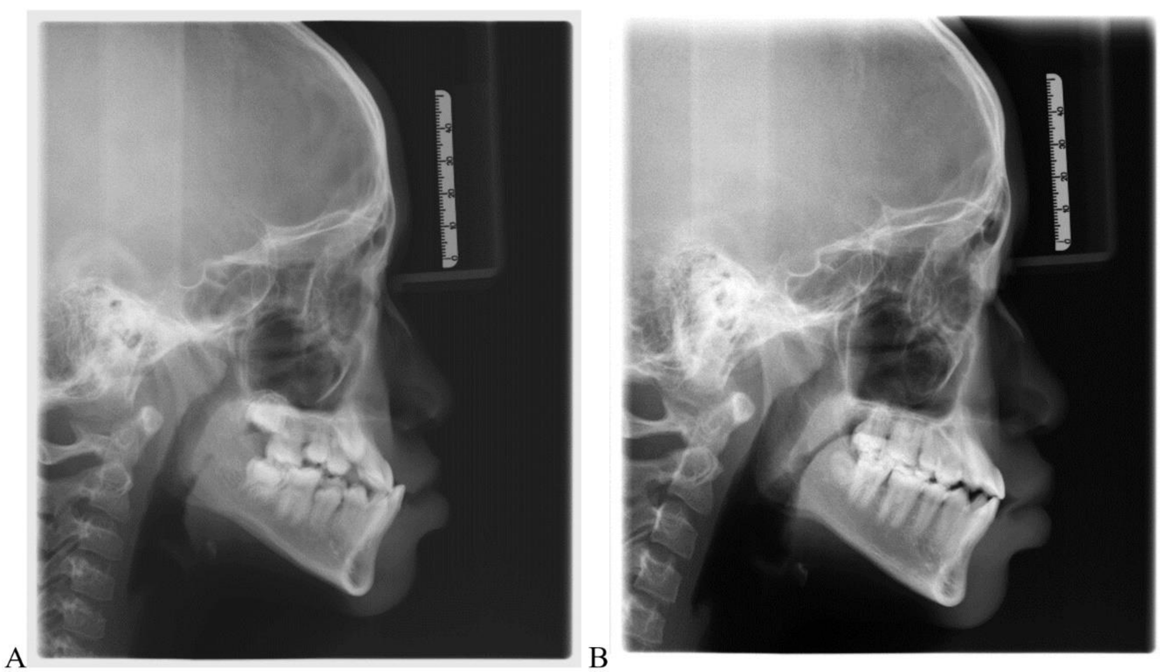

Figure 2: Pre-treatment (A) and post-treatment (B) lateral cephalographs.

Table 1: Skeletal changes in all subjects (n=24) and by age groups before and after treatment

Variables	Pretreatment (n=24)	Posttreatment (n=24)	Δ group (n=24)	p1	Δ1 group 7-10 years (n=18)	Δ2 group 11-12 years (n=6)	p2
SNA (°)	80.47±3.29	82.01±3.51	1.53±0.84	<0.001	1.67±0.91	1.13±0.43	<0.001
SN-PP (°)	9.26±2.87	8.33±2.96	-0.93±1.35	0.003	-1.06±1.50	-0.55±0.70	0.007
A-Np (mm)	-1.63±3.00	-0.17±3.46	1.45±2.10	0.003	1.71±2.39	0.70±0.30	0.008
A-X (mm)	43.78±2.81	45.33±3.17	1.55±1.22	<0.001	1.59±1.37	1.41±0.67	<0.001
A-Y (mm)	59.20±2.98	61.14±3.23	1.93±0.90	<0.001	2.08±0.86	1.50±0.97	<0.001
ANS-X (mm)	39.93±2.32	41.23±3.14	1.30±1.56	<0.001	1.39±1.97	1.01±0.37	0.004
ANS-Y (mm)	62.44±3.18	64.22±3.44	1.77±0.81	<0.001	1.88±0.89	1.44±0.33	<0.001
Co-A (mm)	77.13±3.73	80.62±3.52	3.49±1.82	<0.001	3.70±1.91	2.85±1.44	<0.001
N-A-Pog (°)	-3.28±3.95	1.42±4.39	4.70±2.08	<0.001	4.98±2.16	3.87±1.72	<0.001
SN/OP (°)	16.63±3.71	15.23±3.93	-1.39±2.97	0.031	-1.31±3.32	-1.63±1.67	0.112
FH-SGn (°)	57.66±2.26	58.98±2.55	1.31±1.94	0.003	1.10±2.15	1.95±0.94	0.044
S-Go (mm)	65.27±4.03	66.98±4.41	1.70±1.34	<0.001	1.86±1.50	1.25±0.59	<0.001
N-Me (mm)	103.03±5.83	106.57±6.19	3.53±2.32	<0.001	3.73±2.58	2.96±1.26	<0.001
ANS-Me (mm)	55.90±4.58	58.11±4.49	2.21±1.52	<0.001	2.41±1.61	1.60±1.06	<0.001
SNB (°)	82.26±2.84	80.91±2.94	-1.35±1.34	<0.001	-1.27±1.30	-1.58±1.55	0.001
MP-SN (°)	32.89±3.65	34.22±3.77	1.33±1.38	<0.001	1.26±1.40	1.53±1.42	0.001
Co-Gn (mm)	104.26±4.90	106.86±4.74	2.60±2.04	<0.001	3.02±1.90	1.32±2.09	<0.001
Pog –X (mm)	90.26±5.15	93.83±6.04	3.56±2.60	<0.001	3.98±2.82	2.31±1.26	<0.001
Pog –Y (mm)	59.65±4.80	58.58±5.09	-1.06±1.87	0.009	-0.87±1.55	-1.65±2.71	0.029
B-X (mm)	80.65±4.37	83.90±5.68	3.25±3.18	<0.001	3.50±3.51	2.49±1.93	0.001
B-Y (mm)	60.09±4.64	58.97±4.68	-1.12±1.93	0.009	-0.85±1.67	-1.92±2.59	0.044
Wits (mm)	-7.03±1.98	-3.26±2.86	3.77±1.95	<0.001	3.55±1.98	4.44±1.87	<0.001
ANB (°)	-1.79±1.61	1.10±1.67	2.89±1.05	<0.001	2.94±1.02	2.72±1.23	<0.001

Paired- samples t-test; Δ; Δ1; Δ2: Change between pretreatment and posttreatment

Changes of skeletal measurements after treatment

Table 1 shows skeletal changes in all subjects and by age groups before and after treatment. Most of these changes are significantly different (p<0.001). Particular changes have been described below: A-Y and ANS-Y increased 1.53 ± 0.84 mm (p<0.001) and 1.93 ± 0.90 mm (p<0.001) respectively, indicating that the deepest point of the upper incisor alveolar (A point) and the tip of the anterior nasal spine (ANS point) moved forward following facemask treatment. That lead to the expansion of the SNA angle (1.53 ± 0.84º, p<0.001) and the facial convexity angle (N-A-Pog) (4.70 ± 2.08º, p<0.001). On the other hand, angle formed by the palatal plane and S-N (SN/PP) decreased 0.93 ± 1.35º (p=0.003). B-Y and B-X decreased (1.12 ± 1.93 mm, p<0.001) and (3.25 ± 3.18mm, p<0.001), respectively, indicating that the deepest point of the lower alveolar incisor (B point) moved backward and downward following facemask treatment. SNB angle expressed 1.35 ± 1.34º (p<0.001) of reduction. Moreover, the most anterior point on the bony chin (Pog) also moved backward and downward as Pog-Y reduced 1.06 ± 1.87 mm (p=0.009) and Pog-X reduced 3.56 ± 2.60 mm (p<0.001) respectively. After treatment, the angle between the mandibular plane to the S-N plane (MP/SN) was 1.33 ± 1.38º larger than pretreatment (p<0.001). Furthermore, the anterior facial height (N-Me) increased 3.53 ± 2.32 mm (p<0.001) and the lower anterior facial height (ANS-Me) 2.21 ± 1.52 mm (p<0.001). Wits appraisal significantly decreased by 3.77 ± 1.95 mm (p<0.001). ANB angle, which determines the magnitude of the anteroposterior discrepancy between the maxilla and mandible base, increased 2.89 ± 1.05º (p<0.001) as a result of the larger SNA and smaller SNB post-treatment.

There were differences between the 7-10 year-old group and the 11-12 year-old group in the skeletal changes after treatment. In the 7-10 year-old group, the A point and ANS point moved forward (2.08 ± 0.86 mm; 1.88 ± 0.89 mm) more than in the 11-12 year-old group (1.50 ± 0.97 mm; 1.44 ± 0.33 mm). The maxillary protraction (SNA angle) was greater in the 7-10 year-old group (1.67 ± 0.91mm) than in the 11-12 year-old group (1.13± 0.43mm). The increase in facial convexity angle (N-A-Pog) in the 7-10 year-old group, which was 4.98 ± 2.16º, was more than in the 11-12 year-old group (3.87 ± 1.72º). The total anterior facial height (N-Me) increased to 3.73 ± 2.58mm and 2.96 ± 1.26mm in the 7-10 and 11-12 year-old groups, respectively. Similarly, the lower anterior facial height (ANS-Me) also increased more in the younger group (2.41 ± 1.61mm) in comparison with the older group (1.60 ± 1.06mm). The downward movement of Pog point (Pog-X) was greater in the 7-10 year-old group (3.98 ± 2.82mm) when compared with the 11-12 year-old group (2.31 ± 1.26mm). On the contrary, the Wits appraisal decreased less in the 7-10 year-old group (3.55 ± 1.98mm) than in the 11-12 year-old group (4.44 ± 1.87mm). There was no difference found in the changes in ANB angle and overjet between the 2 groups.

Table 2: Dental changes in all subjects (n=24) and by age groups before and after treatment

Variables	Pretreatment (n=24)	Posttreatment (n=24)	Δ group (n=24)	p1	Δ1 group 7-10 years (n=18)	Δ2 group 11-12 years (n=6)	p2
U1/SN (°)	110.68±6.76	115.26±6.28	4.57±5.32	<0.001	4.32±5.73	5.35±4.23	4.23
U1-X (mm)	63.23±4.02	65.41±4.20	2.17±1.59	<0.001	2.28±1.73	1.83±1.12	1.12
U1-Y (mm)	62.61±3.86	66.62±3.83	4.00±2.22	<0.001	4.40±2.34	2.83±1.33	1.33
U6-X (mm)	56.23±3.78	59.14±4.20	2.91±1.44	<0.001	2.85±1.60	3.08±0.89	0.89
U6-Y (mm)	36.37±2.85	39.96±3.67	3.59±2.09	<0.001	3.78±2.00	3.02±2.45	2.45
U1/NA (°)	30.66±6.83	33.19±6.94	2.52±4.68	0.015	2.27±4.82	3.27±4.59	4.59
L1/MP (°)	92.96±7.05	86.81±6.67	-6.15±6.09	<0.001	-6.33±7.00	-5.59±1.89	1.89
Overjet (mm)	-3.16±1.86	2.67±1.10	5.83±2.19	<0.001	5.95±2.25	5.45±2.12	2.12
Overbite (mm)	1.86±2.10	1.93±1.33	0.06±1.86	0.858	0.22±2.04	-0.39±1.23	1.23
U1/ L1 (°)	124.13±9.67	124.29±9.84	0.16±7.73	0.92	0.04±7.86	0.51±8.03	8.03

Paired- samples t-test; Δ; Δ1; Δ2: Change between pretreatment and posttreatment

Changes of dental measurements after treatment

Table 2 shows dental changes in all subjects and by age groups before and after treatment. U1/SN increased 4.57 ± 5.32º (p<0.001), indicating that the maxillary incisors were significantly proclined during treatment. The upper incisal edge also moved forward as the U1-Y increased 4.00 ± 2.22 mm (p<0.001). A mesialization of the upper first molar was recognized with a greater U6-Y value (3.59 ± 2.09 mm). On the other hand, the angle formed by the lower mandibular incisor to the plane determined by the lower border of the mandible (L1/MP) decreased 6.15 ± 6.09º (p<0.001). The improvement in overjet after treatment was statistically significant (5.83 ± 2.19mm, p<0.001) (**Figure 3**).

The proclination to the SN line of the upper incisor (U1-SN) in the 7-10 year-old group (4.32 ± 5.73º) increased less than in the 11-12 year-old group (5.35 ± 4.23º). However, the upper incisal edge of the 7-10 year-old group particularly moved forward more than the older group as the U1-Y were 4.40 ± 2.34mm and 2.83 ± 1.33mm, respectively. In addition, the 7-10 year-old group had a reduction in L1-MP angle (-6.33 ± 7.00º) more than in the 11-12 year-old group (-5.59 ± 1.89º).

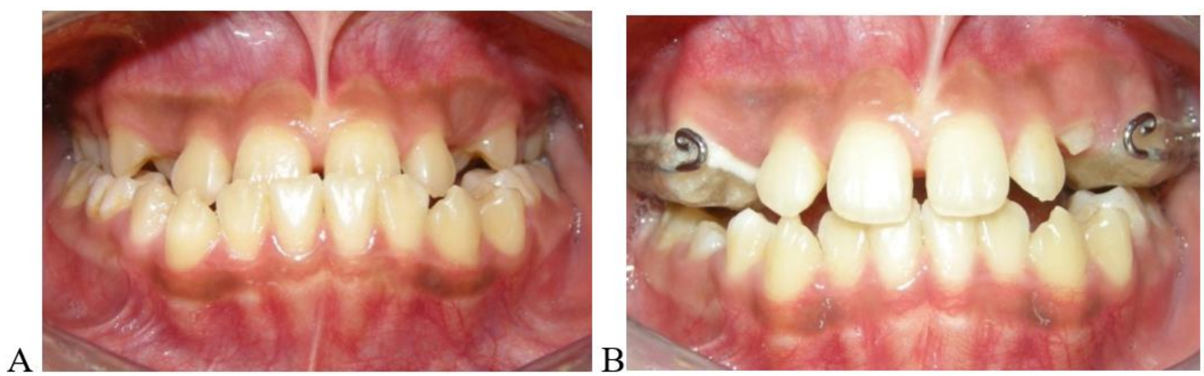

Figure 3: The change of overjet following facemask treatment. A. Intraoral photo of frontal occlusion before treatment of a class III malocclusion patient with an anterior crossbite. B. After facemask treatment, the patient's overjet become positive.

Table 3: Tissue changes in all subjects (n=24) and by age groups before and after treatment

Variables	Pretreatment (n=24)	Posttreatment (n=24)	Δ group (n=24)	p1	Δ1 group 7-10 years (n=18)	Δ2 group 11-12 years (n=6)	p2
Prn –Y (mm)	82.27±3.30	84.73±3.46	2.46±1.23	<0.001	2.63±1.26	1.96±1.08	<0.001
Ls-Y (mm)	76.24±3.75	78.97±3.78	2.72±1.76	<0.001	2.90±1.91	2.20±1.23	<0.001
Li-Y (mm)	77.31±4.88	76.51±4.47	-0.80±2.13	0.078	-0.43±1.86	-1.92±2.67	0.34
Ls- E (mm)	-0.66±1.40	0.88±1.70	1.53±1.13	<0.001	1.46±1.12	1.74±1.23	<0.001
Li - E (mm)	3.56±1.99	2.51±2.09	-1.05±1.06	<0.001	-0.99±1.15	-1.21±0.83	0.002
Nasolabial angle (°)	98.01±12.83	93.57±14.78	-4.43±4.62	<0.001	-4.06±5.15	-5.56±2.45	0.004
Pog(s)-X (mm)	89.39±5.17	92.36±5.42	2.97±2.02	<0.001	3.03±2.23	2.77±1.34	<0.001
Pog(s) – Y (mm)	70.71±5.14	70.54±4.92	-0.17±3.54	0.817	0.16±3.68	-1.17±3.20	0.851

Paired- samples t-test; Δ; Δ1; Δ2: Change between pretreatment and posttreatment

Changes of soft tissue measurements after treatment

All of the soft tissue changes in all subjects and by age groups during treatment measured on cephalographs are described in Table 3. Prn-Y increased by 2.46 ± 1.23mm (p<0.001), meaning that the most anterior point on tip of nose moved forward. The upper lip remarkably protruded as the Ls-Y increased 72 ± 1.76mm (p<0.001). That leads to a significant reduction in the nasolabial angle (-4.43 ± 4.62º, p<0.001). Furthermore, the distances from upper lip and lower lip to the esthetic E-line notably changed with the expansion of Ls-E (1.53 ± 1.13mm, p<0.001) and the shortening of Li-E (-1.05 ± 1.06mm, p<0.001).

Soft tissue changes of post-treatments were found in the two groups. We noticed that the protrusion of upper lip in the 7-10 year-old group (2.90 ± 1.91mm) was higher than in the 11-12 year-old group (2.20 ± 1.23mm), but the nasolabial angle of the 7-10 year-old group nevertheless decreased less than the 11-12 year-old group.

DISCUSSION

The main goal of the treatment of skeletal class III malocclusion with maxillary deficiency is to move the maxillary forward. We can evaluate the maxillary protraction via the increasing SNA angle and the forward movements of A and ANS, represented by the A-Y and ANS-Y distances. The results of this study showed that A and ANS moved forward 1.93mm and 1.77m, respectively, resulted in the 1.53º increasing of SNA and 4.7º expanding of the facial convexity angle (N-A-Pog). All of the statistically significant improvements of the maxillary measurements proved that the facemask could be highly effective in skeletal class III malocclusion treatment. The higher facial convexity angle transformed patients' faces from the concave profile to a straight or convex profile, which helped to improve the patients' facial esthetics. Many previous studies also concluded that during facemask treatment, point A moved 1.78-3.34 mm forward[12,13,14], the ANS point moved 1.89mm forward[12] and the SNA angle enlarged 1.5º-2.35º[(12,14)] on average. The results suggested that after treatment, the mandible rotated clockwise with the B point moved downward 3.25 mm and backward 1.12 mm, together with the 3.56mm downward and -1.06 mm backward reposition of the Pog. This led to the angle between the mandibular plane to S-N plane (MP/SN) enlarging by 1.33º. While the SNA angle increased by 1.53°, the SNB angle decreased by 1.35º. These changes were similar to the results in the studies of Turley[14] and Ngan[15].

This study found that after facemask treatment, the total anterior facial height (N-Me) and the anterior lower facial height (ANS-Me) grew 3.53 ± 2.32 mm and 2.21 ± 1.52 mm, respectively, in combination with enlargement of the MP-SN angle by 1.33 ± 1.38º. A study by Sar[16] recorded the increasing of N-Me, ANS-Me and MP-SN as 2.52 mm, 2.47 mm and 2.16º respectively. In another study, Yuksel and Tortop[17] reported that the N-Me, ANS-Me and MP-SN angles increased by 3.40 mm, 3,10 mm, and 0.8º, respectively. Therefore, our study showed less rotation of the mandible than in Sar's study[16] and fewer changes in the lower facial height than in the study of Sar[16] or Yuksel and Tortop[17] caused by facemask treatment. This study found that the Wits appraisal change 3.77 ± 1.95 mm and the ANB angle increased 2.89 ± 1.05º as a result of increasing SNA and decreasing SNB. Wits' appraisal was used to access the anteroposterior relationship of maxilla and mandible, with more advantages than the ANB angle. The post-treatment increase of Wits appraisal in this study is similar to the changes in Yuksel and Tortop's study[17], but much greater than in Ngan's study[18]. In this study, the maxillary protraction in combination of backward and downward mandibular rotation after facemask treatment helped to correct the maxillary-mandibular relationship in the anteroposterior direction, reduced the severity of skeletal class III occlusion or transformed the skeletal class III to class I relationship.

The results showed that the upper maxillary incisor proclination (U1-SN) increased by 4.57 ± 5.32º while the upper incisal edge moved forward 4.00 ± 2.22 mm. These changes were lower than the results in Liu's study [12]. The upper first molar was mesialized 3.59 ± 2.09 mm. The angle formed by the lower mandibular incisor axis to the mandibular plane (L1-MP) in this study decreased 6.15 ± 6.09º, slightly more than the reduction found in Liu's and Sar's research[12,16]. On the other hand, the overjet changed from negative to positive (increased 5.83 ± 2.19mm). This improvement was much greater than in the previous studies of Yuksel and Tortop[17] and Ngan[18]. Facial esthetics is one of the main goals of the early treatment of skeletal class III malocclusion by using facemasks. The improvement of the facial esthetics is the most impressive effect that can be seen. Our results clearly showed that treatment with facemasks helped to protrude the upper lip by 2.72 ± 1.76mm. As a result, the nasolabial angle was narrower by 4.43 ± 4.62º. Furthermore, the distance from Ls and Li to esthetic E-line was changed which contributed to an improvement in the upper and lower lip relationship. Besides, the most anterior point on tip of nose moved forward 2.46 ± 1.23mm. The forward movement of the nose and lips together with the reduction of nasolabial angle were due to particular changes of the mandibular base, which helped to increase the facial convexity and therefore, improve facial esthetics. Turley *et al.* recorded that the changes of Prn-Y and Ls-Y after treatment were 3.43mm and 3.67mm, respectively[14]. This indicated that the forward movement of Prn and Ls were greater than found in this study. However, Sar measured the same Ls-Y valued as our study[16]. The skeletal and dental protraction of the maxilla recorded in the 7-10 year-old group was more than in the 11-12 year-old group. On the other hand, the maxillary incisors of the older group tended to procline instead of moving forward together with the maxilla. The back and downward rotation of mandible in the 7-10 year-old group was less than in the 11-12 year-old group. Facemask treatment had greater effects on the changes of the maxillomandibular relationship and overjet in the younger group than in the older group. The soft tissue of the 7-10 year-old group was improved more than in the 11-12 year-old group because of the better changes in the maxillary bone. Altogether, our results suggested that facemask treatment is more effective in the 7-10 year-old group than in the 11-12 year-old group.

However, there are some limitations in our study that prevents us from achieving more information. The small sample size made the investigation of different groups of age or gender more difficult. We were unable to examine long-term effects of facemask treatment on study subjects in this research. After finishing the treatment with facemasks, these patients would be continuously observed and treated until achieving optimal occlusion. We did not have a control group because of ethical issues. Using a group of untreated skeletal class III malocclusion patients as a control was the limitation of the previous study because that delayed the treatment to improve the anteroposterior discrepancy of the upper and lower jaws in those patients.

CONCLUSION

A facemask is a highly effective treatment for skeletal class III malocclusion. This treatment led to changes in jaws, teeth and soft tissue. After over a year of using a facemask, the maxilla moved forward, the mandible rotated down and backward, the maxillomandibular relationship was improved, and the anterior facial height and lower anterior facial height were increased. At the same time, the upper incisors proclined labially and the lower incisors reclined lingually, which resulted in the transformation of occlusion from an anterior crossbite to a positive overjet. In addition, the protracted upper lip and narrowed nasolabial angle modified the upper and lower lip relationship. All of these changes helped to improve the patients' facial esthetics.

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