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ORIGINAL RESEARCH

Early treatment of skeletal class III malocclusion with facemask therapy in Vietnam

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Abstract

To evaluate the effects of facemask therapy on skeletal class III malocclusion in the Vietnamese population. This interventional trial enrolled a total of 31 children, dividing them into two age groups: Children aged 7 to 9 (54.8%), who were in the pre-pubescent or early mixed dentition stages, comprised one group. The other group consisted of 14 children, representing 45.2%, who were in the mid-pubescent or late mixed dentition stage, aged 7 to 9. All of them had skeletal class III maxillary deficiency (Angle formed by the A-nasion line and B-nasion line $\leq 0°$, Wits appraisal ≤ 2). The study aimed to investigate how age affects changes in lateral cephalometric measurements before and after treatment. The research involved clinical records, lateral cephalograms, and dental casts. Both qualitative and quantitative variables were evaluated using specific statistical tests. Fisher's exact test was used for qualitative variables, while paired samples *t*-tests and independent samples *t*-tests were used for quantitative variables. In cases where the data did not follow a normal distribution, the Wilcoxon test and Mann-Whitney U-test were used ($p \leq 0.05$). The study found that using a facemask improved the skeletal, dental and soft tissues. It led to a forward movement of the maxilla and a rotation of the mandible, resulting in a better relationship between the maxilla and mandible. The upper incisors shifted from a crossbite to a positive overbite, and the upper lip protruded forward. The concave face became more prominent and aesthetically pleasing. Most individuals (80.6%) had positive outcomes, with the highest proportion among children aged 7–9 years. Based on the study's findings, the facemask was highly effective for both age groups in skeletal class III malocclusion. The group of children aged 7–9 years with maxillary deficiency was more efficacious than the group of children aged 10–12 years.

Keywords

Skeletal class III malocclusion; Early treatment; Facemask therapy; Vietnamese population

1. Introduction

From a clinical perspective, malocclusions are wide-ranging and of diverse types. Among them, skeletal class III malocclusion is considered the most diverse and complex to treat. Orthodontics has made significant progress in treating skeletal class III malocclusion [1, 2]. Class III compensatory orthodontic treatment shows limited results because it primarily affects the teeth rather than the skeletal structure. However, surgical intervention for the treatment of skeletal class III malocclusion is very intricate, and the recovery period is demanding, which is why it is not a preferred option for most patients [3]. Early treatment is critical for skeletal class III malocclusion, reducing the need for surgical treatment throughout adolescence or adulthood [4]. Haas suggested developing an appliance for maxillary expansion that would enhance orthopedic benefits while minimizing dental complications. The acrylic Haas-type expansion appliance was designed to support the transmission of expansion pressures to the maxillary skeletal base by covering both teeth and palatal tissue [5]. It also helped improve psycho-social aspects and achieve facial symmetry. Individuals with underdeveloped maxilla and skeletal class III malocclusion frequently use facemask appliances and skeletal expanders as a fundamental approach to early orthodontic treatment [6, 7]. The prevalence of skeletal class III malocclusion in mixed and permanent dentition varies internationally, ranging from 0.7% in Israel to 19.9% in China [8]. Studies have been conducted in different countries on the craniofacial features of individuals with class III malocclusion, as well as the efficacy of therapy using facemasks and maxillary expansion devices [9, 10]. However, it is difficult to isolate the individual impacts of each approach. Additionally, it is important to mention that early surgical intervention may result in a recurrence due to subsequent growth. The recent advancement of the quick maxilla growth technique has sparked much controversy and necessitates more investigation [11]. More scientific research is necessary to understand the signs of skeletal class III malocclusion in young patients and the effectiveness of facemask appliances in treating malocclusion.

2. Materials and methods

2.1 Study participants

The inclusion criteria encompassed children aged 7–12 years in the cervical vertebral maturation (CVM) method allows classification into six cervical stages (CS1–6), with the C4 cervical vertebrae remaining with a flat bottom border and the C3 and C4 body forming horizontally rectangular or trapezoidal [12]; skeletal class III malocclusion with maxillary deficiency (ANB angle of 0° or less, Wits appraisal of 2 mm or less); and completely erupted initial permanent molars and upper permanent central incisors. The exclusion criteria comprised the congenital absence of permanent teeth or extracted permanent teeth; congenital cleft lip-palate; conditions resulting in the early calcification of the maxilla, such as Crouzon syndrome; and previous orthodontic treatment.

2.2 Study methods

Calculation formula:

$$n = \frac{Z^2_{1-\frac{\alpha}{2}} P(1-P)}{d^2}$$

n is the sample size required for the study;
$Z^2_{1-\frac{\alpha}{2}}$ is the level of confidence;
P is the estimated rate from the previous study. In this study, using $p = 0.885$, the success rate using facemasks was 88.5% of Nardoni's (2015) study [13].

d is the absolute precision.

This interventional trial enrolled a total of 31 children, dividing them into two age groups: children aged 7–9 years (17 children, 54.8%) in the pre-puberty or early mixed dentition stage, referred to as the early treatment group, and those aged 10–12 years (14 children, 45.2%) in the mid-puberty or late mixed dentition stage, referred to as the late treatment group. The clinical records, lateral cephalograms obtained before therapy, and dental casts were taken before- and after treatment, and the treatment outcomes (according to Table 1) were assessed for those who reached the standards for sampling at the Can Tho University of Medicine and Pharmacy. Ethics approval and consent to participate.

2.3 Study procedure

The treatment treated skeletal class III malocclusion with the combination of a facemask (Ormco, Glendora, CA, USA) and anchorage of a palatal expander (Leone, Sesto Fiorentino, Italy) with bite turbo wax. The initial expansion procedure involved advising the patient's parents to rotate the screws by 1/4 turn each day [14]. Weekly follow-up visits continued until the patient achieved horizontal overcorrection. At that point, the expansion was stopped, and the screws remained in position. The facemask stage, which typically lasts for around 10–12 weeks, was begun, with the duration changing depending on the individual's age and the degree of interlocking of the palatine bones [15]. The facemask was installed and customized properly to fit the face shape and ensure the individual's comfort while wearing it (Fig. 1).

TABLE 1. The classification of the treatment outcomes.

Variables	Treatment outcomes		
	Good (3 points)	Moderate (2 points)	Bad (1 point)
Dental			
Anteroposterior			
Angle classification	Class I	Class I/Class III 25%	Class III
Canine relationship	Class I	Class I	Class III
Overjet	2–4 mm	Egde to egde	Egde to egde
Transverse			
Centric occlusion	Maximal intercuspal position	Maximal intercuspal position	Posterior crossbite
Vertical			
Centric occlusion	Maximal intercuspal position	Maximal intercuspal position	Posterior open bite
Overbite	1–3 mm	Egde to egde	Egde to egde
Skeletal			
ANB (°)	Increase	Not increase	Not change
Wits	Decrease	Decrease	Not change
Soft tissue			
Lateral facial profile	Flat/convex	Flat	Concave

Good: 19–27; Moderate: 10–18; Bad: ≤9. ANB: Angle formed by the A-nasion line and B-nasion line.

FIGURE 1. Intraoral and extraoral photographs. (A) The initial expansion procedure; (B) Frontal, and lateral views using a facemask.

2.4 Force application

Two elastics were attached to the hooks located on each side of the maxilla, namely in the vestibular region between the canines and premolars. The other ends of the elastics were connected to the facemask arch's horizontal bar. A force gauge was used to precisely modify the tension of the elastic material, ensuring it exerted a force of 300–450 g on both sides [16]. The proper technique for removing and installing the facemask and correctly wearing the elastic was demonstrated to the patient. We mandated that patients wear the device for a minimum of 12 hours daily, replace the elastic band every 2–3 days, and attend monthly follow-up appointments. They were also guided on proper oral hygiene practices.

Finally, the data were entered into a data collection table and the Statistical Package for Social Sciences (SPSS Statistics for Windows (Version 20.0, IBM Corp., Chicago, IL, USA) was used for analysis.

2.5 Statistical analysis

Statistical analysis was performed using SPSS (version 20.0, IBM Corp., Chicago, IL, USA). For qualitative variables, the frequency (n) and proportion (%) were calculated. For quantitative variables, the mean and median were calculated. Treatment outcomes were assessed utilizing Fisher's exact test for qualitative data, Paired samples t-test and Independent samples t-test for normally distributed quantitative data, and the Wilcoxon test and Mann-Whitney U-test for non-distributed standards. For data to be deemed statistically significant, a threshold of $p \leq 0.05$ was defined.

3. Results

Following treatment, there was a statistically significant forward protrusion of the maxilla, as shown by the results ($p < 0.001$). The SNA angle, which measures the angle between the maxilla and the cranial base, increased by 2.20° ± 1.32°. Additionally, the distance A-Nper (distance from the point pogonion to the line nasion perpendicular to the Frankfort horizontal plane) increased by 1.03 ± 1.47 mm. The maxilla's length (Co-A) increased by 3.35° ± 3.74°. The face convex angle (N-A-Pog: Angle formed by the A-nasion line and A-Pog plane), which had a negative value of −3.81° before treatment, climbed to 5.48° ± 2.72° after treatment, indicating a more convex shape with a change of 1.67°. The angle between the palatal plane (PP) and the anterior cranial base plane (SN) (SN/PP) was reduced by 0.64° ± 1.81°; however, this change was not statistically significant ($p = 0.058$). The occlusal plane (OP) and the anterior cranial base plane angle (SN) (SN/OP) exhibited a statistically significant reduction of 1.04° ± 2.78° ($p = 0.046$). Following therapy, the mandible exhibited a posterior movement, as shown by a substantial reduction in the SNB angle of 1.13° ± 1.74° ($p = 0.001$). The Distance from the point pogonion to the line nasion perpendicular to the Frankfort horizontal plane (Pog-Nperp) distance dropped by a value of 3.05° ± 2.46°. The length of the mandibular bone (Co-Gn: Distance between the condylion and gnathion points) grew considerably by 1.67° ± 3.87° (p = 0.023). The measurements of the mandibular plane angle (SN/MP) and the Frankfort mandibular plane angle (FMA) both showed a substantial rise, with values of 0.95° ± 0.80° and 1.63° ± 1.07°, respectively ($p < 0.001$). The angle of the Y-axis rose by 1.25° ± 2.80° (p = 0.019). The posterior facial height (S-Go) and anterior lower facial height (ANS-Me) increased by 1.63 ± 0.89 mm and 1.94 ± 0.88 mm, respectively, with statistical significance ($p < 0.001$). The overall vertical dimension of the front part of the face (N-Me: Distance between the Nasion and Menton points) showed an increase; however, this change was not statistically significant (p = 0.153). The connection between the two jaw bones showed a considerable improvement following treatment, as shown by the significant rise in both the Wits index (Distance between the projection of A and B points on the occlusal plane) and the ANB angle (Angle formed by the A-nasion line and B-nasion line) 4.71 ± 2.03 mm and 3.36 ± 1.41 mm, respectively, ($p < 0.001$; Table 2). The maxillary incisors were tilted forward 4.12° ± 2.71° relative to the cranial base (U1/SN) and 3.67° ± 4.75° relative to the NA line (nasion-A point plane) ($p < 0.001$). The maxillary incisor bite edge moved forward compared to the NA line by 1.33 ± 1.97 mm (p = 0.001). The maxillary molar moved mesially compared to the line perpendicular to the Frankfort plane passing through PtV- the intersection of the pterygoid vertical (U6-PtV) by 2.53 ± 1.1 mm. The angle between the mandibular central incisor axis and the mandibular plane (L1/MP) decreased by 3.13° ± 2.71° ($p < 0.001$). Overjet increased by 4.87 ± 1.71 mm, which was very significant ($p < 0.001$) while overbite decreased by 0.22 ± 1.95 mm but was not statistically significant (p = 0.537). The relationship between the front teeth changed from crossbite (−) to overbite (+). The interincisal angle (U1-L1) decreased slightly by 0.15 ± 2.14 (p = 0.693; Table 3). The distance between the upper lip and the E aesthetic line showed a significant change ($p < 0.001$), shifting from −1.28 mm behind the E line to 0.55 mm in front of the E line. This resulted in an increase of 1.83 ± 1.31 mm following the treatment. However, the distance from the lower lip to aesthetic line E (Li-E) dropped by 0.25 ± 0.84 mm, although this change was not statistically significant (p = 0.107). The nasolabial angle exhibited a reduction; however, this change did not reach statistical significance (p = 0.597; Table 4). Following treatment, there was a statistically significant forward protrusion of the maxilla in both groups ($p < 0.001$). In the group of children aged 7–9 years, the maxillary prominence (SNA angle) and maxillary bone length (Co-A) rose more than in the group of children aged 10–12 years. Specifically, the SNA angle increased by 2.27° ± 1.32° in the 7–9-year-old group, whereas it increased by 2.11° ± 1.36° in the 10–12-year-old group. Similarly, the maxillary bone length increased by 3.81 ± 3.51 mm in the 7–9-year-old group but 2.79 ± 4.06 mm in the 10–12-year-old group. The face convex angle (N-A-Pog) showed a statistically significant rise in both groups ($p < 0.001$), with a greater increase seen in the 7–9-year-old group than in the 10–12-year-old group (5.12° *vs.* 4.87°). The SN/PP angle (angle between the anterior cranial base plane and palatal plane) declined by the same amount in both age groups, with values of −0.66° ± 1.66° and −0.62° ± 2.05°, respectively. The occlusal plane and skull base angle (SN/OP) reduced considerably (p = 0.007) in the 7–9-year-old group, whereas the 10–12-year-old group exhibited a non-significant opposite outcome (p = 0.583). The SNB angle exhibited a greater drop in the 10–12-year-old group (−1.7° ± 1.7°) than in the 7–9-year-old group (−0.65° ± 1.68°), and this difference was statistically significant (p = 0.002). The Pog point exhibited a greater posterior movement (Pog-Nperp) in the 10–12-year-old group (−3.15 ± 1.67 mm) than in the 7–9-year-old group (−2.97 ± 3.01 mm). The length of the mandibular bone (Co-Gn) showed a considerable increase in the 7–9-year-old group compared to the 10–12-year-old group, with a statistically significant difference (p = 0.032). The mandibular plane angle (SN/MP) exhibited a greater rise in the 10–12-year-old group (1.03°) than in the 7–9-year-old group (0.83°). The increase in anterior lower facial height (ANS-Me) was greater in the 7–9-year-old group (2.04 ± 1.00 mm) than in the 10–12-year-old group (1.82 ± 0.74 mm). The Wits index and ANB angle showed greater increases in the 7–9-year-old group (5.14 ± 2.14 mm and 3.05°, respectively) than in the 10–12-year-old group (4.2 ± 1.83 mm and 2.96°, respectively; Table 5). In the 7–9-year-old group, the maxillary incisors were inclined forward about the anterior cranial base plane SN line (U1/SN) at an angle of 5.12° ± 2.06°, which was more than the inclination seen in the 10–12-year-group, at 2.9° ± 2.96°. In the 7–9-year-old group, the front edge of the upper incisors moved forward more relative to the NA line (U1-NA) by an average of 1.81 ± 1.34 mm. This difference was statistically significant ($p < 0.001$) compared to the movement in the 10–12-year-old group, which was only 0.74 ± 2.47 mm. The overjet in the 7–9-year-old group had a greater change compared to that in the 10–12-year-old group, with an increase of 5.17 ± 1.8 mm as opposed to 4.51 ± 1.58 mm. In the 7–9-year-old group, the angle between the axis of the mandibular central incisor and the mandibular plane (L1/MP) fell by −3.82° ± 1.58°, which was a greater reduction than in the 10–12-year-old group (−2.28° ± 3.53°; Table 6). The measurement of the distance from the upper lip to the aesthetic line E (Ls-E) showed a greater rise in the 10–12-year-old group (1.95 ± 1.5 mm) than in the 7–9-year-old group (1.73 ± 1.18 mm). Conversely, the lower lip in the 10–12-year-old group had a greater degree of recession (−0.39 ± 1.13 mm) than in the 7–9-year-old group (−0.13 ± 0.49 mm). The nasolabial angle showed a reduction in the group of children aged 7–9 (−2.47 ± 7.36) but an increase in the group of children aged 10–12 (2.89 ± 18.27). Nevertheless, these disparities did not possess any statistical significance, with a p-value of 0.317 (Table 7). Out of the 25 patients, 80.6% had positive outcomes. Among them, 15 patients (88.2%) were in the 7–9-year-old group, and the proportion was 1.5 times higher in the 10–12-year-old group. The average treatment outcomes for both age groups were identical, with two instances each. None of the patients between the ages of 7 and 9 years had unsatisfactory outcomes. Out of all the patients, only two experienced unfavorable outcomes, representing 14.3% of the total. These two patients were between the ages of 10 and 12 years (Table 8).

TABLE 2. Skeletal index changes before and after treatment.

Variables	Definitions	Pre-treatment	Post-treatment	Δ Change	*p*
Maxilla					
SNA (°)	Angle formed by the anterior cranial base plane and A-nasion line	79.37	81.57	2.20 ± 1.32	<0.001*
A-Nperp (mm)	Distance from point A to the line nasion perpendicular to the Frankfort horizontal plane	−2.67	−1.64	1.03 ± 1.47	<0.001*
Co-A (mm)	Distance between the Condylion and A points	76.54	79.89	3.35 ± 3.74	<0.001*
N-A-Pog (°)	Angle formed by the A-nasion line and A-Pog plane	−3.81	1.67	5.48 ± 2.72	<0.001*
SN/PP (°)	Angle between the anterior cranial base plane and palatal plane	8.35	7.70	−0.64 ± 1.81	0.058*
SN/OP (°)	Angle between the anterior cranial base plane and occlusal plane	18.05	17.01	−1.04 ± 2.78	0.046*
Mandible					
SNB (°)	Angle formed by the anterior cranial base plane and B-nasion line	81.39	80.26	−1.13 ± 1.74	0.001*
Pog-Nperp (mm)	Distance from the point pogonion to the line nasion perpendicular to the Frankfort horizontal plane	−4.23	−7.28	−3.05 ± 2.46	<0.001*
Co-Gn (mm)	Distance between the condylion and gnathion points	105.67	107.34	1.67 ± 3.87	0.023*
SN/MP (°)	Angle between the anterior cranial base plane and mandibular plane	31.97	32.92	0.95 ± 0.80	<0.001*
FMA (°)	Angle between the Frankfort plane and mandibular plane	27.61	29.24	1.63 ± 1.07	<0.001*
Y-Axis (°)	Angle between the Frankfort plane and S-Gnathion line	60.81	62.06	1.25 ± 2.80	0.019*
S-Go (mm)	Distance between the Sella and Gonion points	68.28	69.91	1.63 ± 0.89	<0.001*
N-Me (mm)	Distance between the Nasion and Menton points	107.51	109.22	2.06 ± 5.73	0.153**
ANS-Me (mm)	Distance between the anterior nasal spine and Menton points	63.71	65.65	1.94 ± 0.88	<0.001*
The relative position of the maxilla to the mandible					
Wits (mm)	Distance between the projection of A and B points on the occlusal plane	−8.31	−3.60	4.71 ± 2.03	<0.001*
ANB (°)	Angle formed by the A-nasion line and B-nasion line	−1.98	1.37	3.36 ± 1.41	<0.001*

**Paired samples t-test, **Wilcoxon test, Δ: Change between pre- and post-treatment.*
SNA: the angle formed between points S, N and A, indicating the anteroposterior projection of the maxilla sella nasion subspinale angle; SN: anterior cranial base plane; PP: palatal plane; OP: Occlusal plane; SNB: the angle formed between points S, N and B, indicating the anteroposterior projection of the mandible; MP: mandibular plane; FMA: The Frankfort-mandibular plane angle, Y-Axis: Angle formed from ST G and sella-nasion; S-Go: posterior facial height; N-Me: anterior facial height; ANS: anterior nasal spine; ANB: Angle formed by the A-nasion line and B-nasion line.

TABLE 3. Dental index changes before and after treatment.

Variables	Definitions	Pre-treatment	Post-treatment	Δ Change	p
U1/SN (°)	Angle formed by the long axis of the upper incisor and the anterior cranial base plane	105.80	109.92	4.12 ± 2.71	<0.001*
U1/NA (°)	Angle formed by the long axis of the upper incisor and the A-nasion line	25.81	29.47	3.67 ± 4.75	<0.001*
U1-NA (mm)	Distance from the upper incisor tip to the A-nasion line	5.80	7.13	1.33 ± 1.97	0.001*
U6-PtV (mm)	Distance from the upper first molar to the line perpendicular to Ptm	7.76	10.30	2.53 ± 1.10	<0.001*
L1/MP (°)	Angle formed by the long axis of the lower incisor and the mandibular plane	89.00	85.88	−3.13 ± 2.71	<0.001*
Overjet (mm)	Horizontal distance between the upper and lower central incisors measured parallel to the occlusal plane	−1.92	2.39	4.87 ± 1.71	<0.001**
Overbite (mm)	Vertical distance between the incisal edge of the upper central incisor and the incisal edge of the lower central incisor	1.71	1.49	−0.22 ± 1.95	0.537*
U1-L1 (°)	Angle formed by the long axis of the upper and lower incisor	129.77	129.62	−0.15 ± 2.14	0.693*

**Paired samples t-test, ** Wilcoxon test, Δ: Change between pre- and post-treatment.*
U1: upper incisor; L1: lower incisor; U6: upper first molar; SN: anterior cranial base plane; NA: nasion-A point plane; MP: mandibular plane; PtV: the intersection of the pterygoid vertical.

TABLE 4. Soft tissue index changes before and after treatment.

Variables	Definitions	Pre-treatment	Post-treatment	Δ Change	p
Ls-E (mm)	Distance from the Ls point to the E-line	−1.28	0.55	1.83 ± 1.31	<0.001*
Li-E (mm)	Distance from the Li point to the E-line	2.17	1.92	−0.25 ± 0.84	0.107*
Nasolabial angle (°)	Angle formed by the Cm-Sn line and UL-Sn line	86.97	87.71	−0.05 ± 13.45	0.597**

**Paired samples t-test, **Wilcoxon test, Δ: Change between pre- and post-treatment.*
Ls-E: The horizontal distance between labralesuperious and esthetic line. It measures the relative protrusion of the upper lip to the esthetic line. Li-E: The horizontal distance between labraleinferius and esthetic line. It measures the relative protrusion of the lower lip to the esthetic line. UL-Sn: The distance from upper lip to Steiner's S line. Cm-Sn: columella of nose to subnasale.

4. Discussion

The study found that facemask therapy effectively addressed skeletal class III conditions in the maxilla, particularly in the incisor alveolar bone region. The maxilla underwent anterior displacement, leading to an increase in the SNA angle, the distance between points A and N on the Frankfort plane, maxillary bone length and face projection. The SNA angle increased from 0.80° to 1.1° in the facemask group and 2.2° in the facemask group using palatal anchoring screws. The study found a significant increase of 2.20° ± 1.32° compared to previous studies [17, 18]. The study found that the palatal plane turns anticlockwise because the angle between it and the base of the skull got smaller after treatment (SN/PP −0.64° ± 1.81°). However, this drop was not statistically significant (p = 0.058). The pulling force did not align with the maxilla's center of resistance, causing the face to rotate and flatten. To mitigate this, the hook on the intraoral anchoring appliance was positioned higher near the maxillary canine teeth, and the horizontal bar of the facemask appliance was modified to form a 30° angle with the occlusal plane [19]. The study found that after facemask treatment, there was an average increase in SNA and a decrease in SNB, with positive impacts on skeletal connections. The ANB angle and Wits index indices showed significant increases. A randomized controlled clinical trial in the UK showed that the ANB angle shifted by 2.6° and 1.0° after 15 months and 3 years of therapy, respectively [20]. At 6 years, the change in ANB angle was 4° and 0.0°, respectively. The efficacy of facemask therapy diminishes with time because of the delayed mandibular development after the treatment period. Most doctors expect that a skeletal class III growth will eventually return to its normal state in the long run. However, compared to the control group, the treatment group exhibited an ANB angle that was about 1° more favorable and maintained a positive overbite of over 1 mm after 6 years. Most importantly, the group treated with facemasks had a much-decreased need for surgical therapy. To summarize, the therapeutic effects of skeletal and occlusal

TABLE 5. Skeletal index changes before and after treatment by age group.

Variables	Definitions	7–9 yr		10–12 yr		p
		Mean ± SD	p	Mean ± SD	p	
Maxilla						
SNA (°)	Angle formed by the anterior cranial base plane and A-nasion line	2.27 ± 1.32	<0.001*	2.11 ± 1.36	<0.001*	0.750[a]
A-Nperp (mm)	Distance from point A to the line nasion perpendicular to the Frankfort horizontal plane	0.87 ± 1.68	0.048*	1.22 ± 1.19	0.002*	0.528[a]
Co-A (mm)	Distance between the Condylion and A points	3.81 ± 3.51	<0.001*	2.79 ± 4.06	0.023*	0.458[a]
N-A-Pog (°)	Angle formed by the A-nasion line and A-Pog plane	5.12 ± 2.79	<0.001*	4.87 ± 3.34	<0.001*	0.953[b]
SN/PP (°)	Angle between the anterior cranial base plane and palatal plane	−0.66 ± 1.66	0.122*	−0.62 ± 2.05	0.276*	0.961[a]
SN/OP (°)	Angle between the anterior cranial base plane and occlusal plane	−2.18 ± 2.64	0.007**	0.35 ± 2.32	0.583*	0.009[a]
Mandible						
SNB (°)	Angle formed by the anterior cranial base plane and B-nasion line	−0.65 ± 1.68	0.130*	−1.70 ± 1.70	0.002*	0.094[a]
Pog-Nperp (mm)	Distance from the point pogonion to the line nasion perpendicular to the Frankfort horizontal plane	−2.97 ± 3.01	0.001*	−3.15 ± 1.67	<0.001*	0.844[a]
Co-Gn (mm)	Distance between the condylion and gnathion points	3.66 ± 2.63	0.875**	0.21 ± 6.34	0.727*	0.032[b]
SN/MP (°)	Angle between the anterior cranial base plane and mandibular plane	0.83 ± 0.62	<0.001*	1.03 ± 0.48	0.001*	0.351[b]
FMA (°)	Angle between the Frankfort plane and mandibular plane	1.42 ± 0.63	<0.001*	1.67 ± 1.06	<0.001*	0.500[b]
Y Axis (°)	Angle between the Frankfort plane and S-Gnathion line	0.92 ± 2.92	0.213*	1.65 ± 2.68	0.038*	0.477[a]
S-Go (mm)	Distance between the S and Gonion points	1.70 ± 0.85	<0.001*	1.54 ± 0.95	<0.001*	0.625[a]
N-Me (mm)	Distance between the Nasion and Menton points	2.33 ± 7.08	0.007**	0.15 ± 14.22	0.510**	0.062[b]
ANS-Me (mm)	Distance between the anterior nasal spine and Menton points	2.04 ± 1.00	<0.001*	1.82 ± 0.74	<0.001*	0.509[a]
The relative position of the maxilla to the mandible						
Wits (mm)	Distance between the projection of A and B points on the occlusal plane	5.14 ± 2.14	<0.001*	4.2 ± 1.83	<0.001*	0.207[a]
ANB (°)	Angle formed by the A-nasion line and B-nasion line	3.05 ± 1.76	<0.001*	2.96 ± 3.12	<0.001*	0.226[b]

**Paired samples t-test, **Wilcoxon test.*
[a]Independent samples t-test; [b]Mann-Whitney U-test.
SNA: the angle formed between points S, N and A, indicating the anteroposterior projection of the maxilla sella nasion subspinale angle; SN: anterior cranial base plane; PP: palatal plane; OP: Occlusal plane; SNB: the angle formed between points S, N and B, indicating the anteroposterior projection of the mandible; MP: mandibular plane; FMA: The Frankfort-mandibular plane angle; Y-Axis: Angle formed from ST G and sella-nasion; S-Go: posterior facial height; N-Me: anterior facial height; ANS: anterior nasal spine; ANB: Angle formed by the A-nasion line and B-nasion line.
SD: Standard deviation.

TABLE 6. Dental index changes before and after treatment by age group.

Variables	Definitions	7–9 yr		10–12 yr		p**
		Mean ± SD	p	Mean ± SD	p	
U1/SN (°)	Angle formed by the long axis of the upper incisor and the anterior cranial base plane	5.12 ± 2.06	<0.001*	2.9 ± 2.96	0.003*	0.020[a]
U1/NA (°)	Angle formed by the long axis of the upper incisor and the A-nasion line	4.9 ± 4.86	0.001*	2.17 ± 4.31	0.082*	0.112[a]
U1-NA (mm)	Distance from the upper incisor tip to the A-nasion line	1.81 ± 1.34	<0.001*	0.74 ± 2.47	0.284*	0.133[a]
U6-PtV (mm)	Distance from the upper first molar to the line perpendicular to Ptm	2.71 ± 0.82	<0.001*	2.32 ± 1.37	<0.001*	0.340[a]
L1/MP (°)	Angle formed by the long axis of the lower incisor and the mandibular plane	−3.82 ± 1.58	<0.001*	−2.28 ± 3.53	0.031*	0.116[a]
Overjet (mm)	Horizontal distance between the upper and lower central incisors measured parallel to the occlusal plane	5.17 ± 1.80	<0.001**	4.51 ± 1.58	0.001**	0.294[a]
Overbite (mm)	Vertical distance between the incisal edge of the upper central incisor and the incisal edge of the lower central incisor	0.09 ± 0.55	0.407*	0.18 ± 1.17	0.830*	0.095[b]
U1-L1 (°)	Angle formed by the long axis of the upper and lower incisor	0.17 ± 0.17	0.180*	0.16 ± 0.45	0.098*	0.340[b]

**Paired samples t-test, **Wilcoxon test.*
[a]Independent samples t-test, [b]Mann-Whitney U-test.
U1: upper incisor; L1: lower incisor; U6: upper first molar; SN: anterior cranial base plane; NA: nasion-A point plane; MP: mandibular plane; PtV: the intersection of the pterygoid vertical.
SD: Standard deviation.

TABLE 7. Soft tissue index changes before and after treatment by age group.

Variables	Definitions	7–9 yr		10–12 yr		p
		Mean ± SD	p	Mean ± SD	p	
Ls-E (mm)	Distance from the Ls point to the E-line	1.73 ± 1.18	<0.001*	1.95 ± 1.50	<0.001*	0.649[a]
Li-E (mm)	Distance from the Li point to the E-line	−0.13 ± 0.49	0.273*	−0.39 ± 1.13	0.220*	0.406[a]
Nasolabial (°)	Angle formed by the Cm-Sn line and UL-Sn line	−2.47 ± 7.36	0.193*	2.89 ± 18.27	0.564*	0.317[a]

**Paired samples t-test, [a]Independent samples t-test.*
Ls-E: The horizontal distance between labralesuperious and esthetic line. It measures the relative protrusion of the upper lip to the esthetic line. Li-E: The horizontal distance between labraleinferius and esthetic line. It measures the relative protrusion of the lower lip to the esthetic line. UL-Sn: The distance from upper lip to Steiner's S line. Cm-Sn: columella of nose to subnasale.
SD: Standard deviation.

TABLE 8. The relationship between treatment outcomes and age group.

Age group	Treatment outcome		
	Good	Moderate	Bad
7–9 yr	15 (88.2)	2 (11.8)	0 (0.0)
10–12 yr	10 (71.4)	2 (14.3)	2 (14.3)
Total	25 (80.6)	4 (12.9)	2 (6.5)

displacement, albeit not individually substantial, together influence the clinical choice to avoid surgery. The association of the skeletal structure was also assessed using the Wits index due to the prevailing belief among many writers that the ANB measurement is not reliable [21]. The studies conducted by Menéndez Díaz and Weitao Liu saw a rise in the Wits index of 2.18 mm and 3.28 mm, respectively, which was less than this present study [17, 22]. The use of both kinds of appliances simultaneously in the current effectively capitalized on the rotation of the skeletal structures, resulting in a substantial enhancement of the interrelation between them.

Within the field of growth research, the primary focus is on identifying the stable central point from which parameters can be determined and changes may be predicted. Ricketts concluded that the center in question is situated close to the foramen rotundum, which is the exit point for the maxillary nerve branch (V2) from the skull. The anterior movement of the upper lip, along with the forward displacement of the maxilla and maxillary incisors, resulted in a decreased distance between the upper lip and the E aesthetic line. This, combined with the reduction of the nasolabial angle and the protrusion of the lower lip, significantly improved the patients' facial harmony and aesthetic appeal.

The success of orthodontic therapy in children with skeletal class III malocclusion mostly relies on their development potential. Hence, it would be advantageous for physicians to ascertain the appropriate timing for wearing the device to achieve the most favorable therapeutic outcomes. While some studies have suggested that anteroposterior modifications may occur until the beginning of adolescence, the likelihood of skeletal changes seems to diminish at the age of 8 years and continues to decline thereafter. The onset of clinical deterioration often occurs between the ages of 10 and 11 years. In this study, the rate of good results was as high as 80.6%. However, it was still lower than Daniele (2015), which was 88.5%. Daniele (2015) performed the procedure at the onset of treatment and after a mean period of 6 years and 10 months to complete pubertal growth, whereas the average time in this study was about 12 months [13]. This study demonstrated a greater anterior movement of the bones and upper teeth in the 7–9-year-old group than in the 10–12-year-old group. In the 10–12-year-old group, a greater downward and backward rotation of the mandible occurred than in the 7–9-year-old group. The connection between the maxilla and mandible underwent more modifications in the 7–9-year-old group than in the 10–12-year-old group. After treatment, the younger group had a more pronounced forward projection in profile than the older group. This may be attributed to a greater degree of alteration in the maxillary bone base in the early treatment group. According to the Wits index and ANB angle, the 7–9-year-old group had a larger growth than the 10–12-year-old group. Takada observed a significant treatment benefit throughout the pre-pubertal phase (ages 7–9), with a 2.16 mm increase in maxillary length after 13 months [23]. Nevertheless, Yüksel and colleagues demonstrated no statistically significant difference between the groups of children aged 8–10 and 11–14 years [24].

This therapy relies on external equipment, and the effectiveness of the treatment depends on how well the patient follows the given instructions. Thus, it is necessary for physicians to provide encouragement and for families to actively assist the patient. The present study team used a time journal to enable pediatric patients to document their daily wearing time and emotional state. This allowed parents and clinicians to closely evaluate the progress of the therapy and provide immediate assistance in resolving the children's challenges.

Additional studies should be conducted to study the long-term stability of the treatment results for skeletal class III malocclusion using a facemask appliance. It is important to examine the unique recurrence patterns in individuals who were treated early *vs.* those who were treated later. Additionally, it is necessary to determine whether surgical intervention is required after the patient has finished growing.

5. Conclusions

The use of a facemask appliance affected patients' skeletal, dental and soft tissues. The maxilla underwent anterior protrusion, as evidenced by significant increases in the SNA, A-Nperp and Co-A angles. The mandible underwent posterior and inferior rotation simultaneously, resulting in significant changes in their skeletal relationship. The upper incisors showed a forward inclination, while the lower incisors displayed a downward inclination toward the tongue, transitioning from a crossbite to a positive overbite with skeletal class III malocclusion and maxillary deficiency. This held regardless of whether the individual was in the early or late phases of mixed dentition. In the 7–9 age group, the therapy had a clear advantage and significantly improved facial aesthetics throughout the growth process. Early therapy also provided significant psychological benefits.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

AUTHOR CONTRIBUTIONS

LNL and TKL—collected and analyzed the data. LNL, TKL, TTD and KPVL—designed the research study and wrote the manuscript. LNL, TKL, TTD and KPVL—reviewed and edited the manuscript. All authors read and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This retrospective study was conducted according to the guidelines of the Declaration of Helsinki and all procedures performed were following the Ethics Committee of the University of Medicine and Pharmacy of Can Tho University in Biomedical Research No. 551/PCT-HDDD. All children in the manuscript are consent of the parent or guardian for the use of the photographs.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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