Timing for effective application of anteriorly directed orthopedic force to the maxilla

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Class III malocclusion with retrusive maxilla can be orthopedically corrected in the deciduous and mixed dentition, with reverse-pull headgear in combination with rapid palatal expansion. The literature recommends this procedure be carried out before the patient is 8 years old to obtain the optimal orthopedic result. This statement, however, has not been supported by scientific data. The current study examined the treatment effects of patients younger than 8 years old (5 to 8 years) and patients older than 8 years old (9 to 12 years). Thirty patients treated with maxillary protraction and expansion in the Department of Children's Dentistry and Orthodontics, University of Hong Kong were included in this study. Cephalometric radiographs were taken 6 months before the initiation of treatment (T_0), at the initiation of treatment (T_1), and after 6 months of treatment (T_2). In this way, (T_2-T_1) represented cephalometric changes during the treatment period and (T_1-T_0) represented 6 months of growth changes without treatment. Experimental subjects served as their own control in this study. A grid system consisting of maxillary occlusal plane (OL) and a line perpendicular to OL through sella (OLp) was used for linear measurements. A total of 15 linear and 3 angular cephalometric measurements were made. A multivariate analysis of variance (MANOVA), which used age and treatment time as its factors, was used to determine effect of age and/or treatment on each cephalometric parameter. Results indicated strikingly similar therapeutic response between the younger and older age groups. These data suggest that similar skeletal response can be obtained when maxillary protraction was started either before age 8 (5 to 8 years) or after age 8 years (8 to 12 years). (Am J Orthod Dentofac Orthop 1997;112:292-9.)

Reverse-pull headgear in combination with rapid palatal expansion devices has been shown to be effective in correcting Class III malocclusion with maxillary retrusion.[1-3] However, the timing for effective application of anteriorly directed orthopedic force remains unclear. According to McNamara,[4] the optimal time to begin an early Class III treatment regimen is in the early mixed dentition coincident with the eruption of the upper permanent central incisors. Hickham[5] advised that for optimal orthopedic result, this treatment should be initiated before the patient is 8 years old. Proffit[6] recommended that maxillary protraction be initiated before the age of 9 years to produce more skeletal change and less dental movement. However, no data were presented to support these statements. Recently, Takada[7] reported that maxillary protraction and chincup therapy were effective through puberty. The purpose of this study was to determine the effect of maxillary protraction when treatment was initiated before and after 8 years of age in the mixed dentitions. We hypothesized that greater orthopedic effect and less dental movement would be obtained by initiating treatment before the age of 8 years.

MATERIALS AND METHODS

Thirty patients who were treated with maxillary protraction and expansion in the Department of Children's Dentistry and Orthodontics, Faculty of Dentistry, the University of Hong Kong were divided into two groups. Fig. 1 shows the age distribution of the 15 patients in each group. The first group comprised of 10 girls and 5 boys between ages 5 and 8 years at the start of treatment (mean = 6.8 ± 0.9 years). The second group comprised of 10 girls and 5 boys between ages 9 and 12 years at the start of treatment (mean= 10.2 ± 1.2 years). Criteria for patient selection included: (1) mixed dentition, (2) reverse overjet, (3) cephalometric

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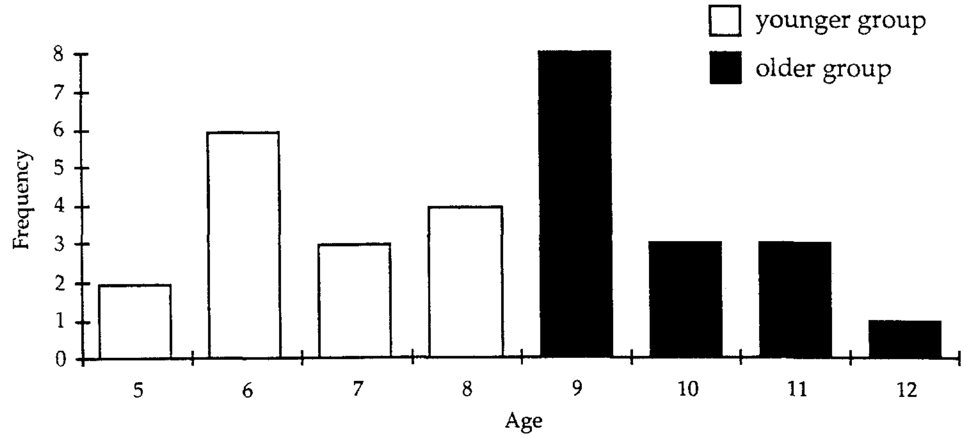


Fig. 1. Frequency of distribution of subject age at treatment initiation (T_1).

Table I. Changes of cephalometric measurements in 30 patients 6 months before the start of treatment (T_0), immediately before treatment (T_1) and 6 months after treatment (T_2)

	T_0		T_1		T_2	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Maxillary position (SNA)	81.0	3.5	80.9	3.7	82.3	3.4***
Mandibular position (SNB)	80.9	2.6	81.1	2.7	79.4	2.5***
Sagittal jaw relation (ANB)	0.0	1.8	−0.2	2.2	2.8	2.0***
Palatal plane (Ans-Pns/SN)	9.3	3.0	9.4	3.3	8.4	3.2*
Mandibular plane angle (Tgo-M/SN)	34.8	3.4	34.6	4.0	36.5	4.0**
Occlusal plane angle (OL/SN)	22.2	3.1	22.6	3.9	20.6	3.4**
Lower face height (Ans-Me)	58.9	3.3	59.9	3.1	63.0	3.5***
Maxillary incisal angle	104.5	8.9	104.8	11.0	108.2	9.0 NS
Mandibular incisal angle	90.3	7.5	90.7	9.2	85.6	6.6**

NS, not significant; ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.
p values at T_2 refer to tests for significant differences between treatment (T_1 to T_2) and control (T_0 to T_1) time periods.

data indicating a Class III skeletal pattern with maxillary retrusion, and (4) completion of at least 6 months of headgear wear. Table I shows the pretreatment skeletal and dental structure of the 30 patients and the cephalometric measurements with 6 months of growth and 6 months of treatment.

Patients were treated with a Hyrax rapid palatal expansion appliance and a Tubinger reverse-pull headgear (Dentaurum, Inc.) (Figs. 2 and 3). The expansion appliance was activated twice daily (0.25 mm per turn) for 10 days. The headgear was worn 12 to 14 hours per day for at least 6 months. Elastics were worn from the soldered buccal hooks on the expansion appliance to the headgear and delivered 380 gm of anterior force per side at an angle of 30° downward from the occlusal plane. Treatment continued until attainment of a positive overjet and Class I molar relationship.

Standardized lateral cephalograms of each patient were taken at the following time periods: 6 months before the initiation of treatment (T_0), at the initiation of treatment (T_1), and after 6 months of treatment (T_2). In this way, (T_2-T_1) represented cephalometric changes during the treatment period and (T_1-T_0) represented 6 months of growth changes without treatment. Comparison of (T_2-T_1) and (T_1-T_0) showed effects as a result of appliance therapy alone. Thus experimental subjects served as their own controls in this study.

All radiographs were traced and measured twice. Mean values and standard deviations were reported. Conventional cephalometric measurements (Table I) and a cephalometric measurements described by Pancherz[8,9] (Tables II and III) were used to describe changes with growth and treatment. The cephalometric landmarks and constructed lines were shown in Fig. 4. The Pancherz method used a grid system that consisted of a maxillary occlusal plane (OL) and a line perpendicular to OL through sella (OLp) for linear measurements. The grid was traced on the first radiograph (T_0), then superimposed onto the second and third radiographs (T_1 and T_2), with a method described by Buschang et al.[10] A total of 15 linear and 3 angular cephalometric measurements were used.

A multivariate analysis of variance (MANOVA), which

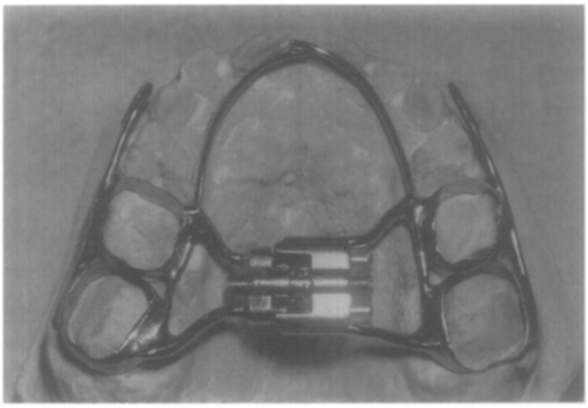


Fig. 2. Hyrax rapid palatal expansion appliance with labial wire soldered to maxillary molar bands and extended to canine area for attachment to elastics.

used age and treatment time as factors, was used to determine whether there was any significant effect of age and/or treatment on each of the cephalometric parameters tested. The test was conducted at a 5% significance level.

RESULTS

Pretreatment Structure of the Two Groups

Tables II and III show the sagittal and vertical cephalometric measurements, respectively, for the two age groups at time periods T_0, T_1, and T_2. Before treatment (T_0), both the younger and older age groups presented with 2.4 mm reverse overjet and a Class III molar relationship (–3.3 and –4.0, respectively). No significant differences were found in any of the sagittal or vertical measurements at T_0 between the two age groups. In general, the older group showed slightly greater values for most of the linear measurements.

Treatment versus Control

After 6 months of treatment, significantly greater changes were observed in 14 of the 18 cephalometric variables, when treatment (T_2-T_1) was compared with the control (T_1-T_0) periods in both the younger and older age groups (Tables II and III). This included significant forward movement of the maxilla (A-OLp), posterior movement of the chin (Pg-OLp), labial tipping of the maxillary incisors (Is-OLp), and lingual tipping of the mandibular incisors (Ii-OLp). Both groups attained a positive overjet (younger group: 4.2 mm; older group: 3.9 mm) and corrected molar relationship (0.6 mm; 0.1 mm) as a result of the skeletal and dental changes. For vertical measurements, both groups showed an increase in lower facial height

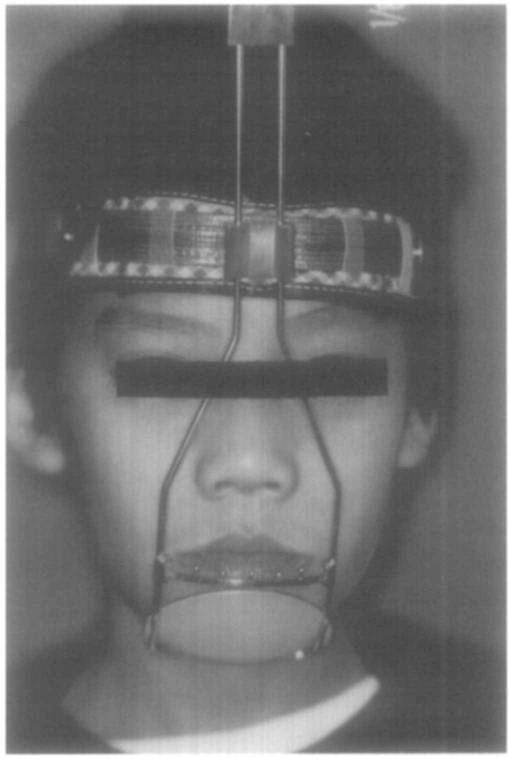


Fig. 3. Tubinger reverse-pull headgear with elastics that delivered 380 gm of maxillary protraction force each side, 30°o downward from occlusal plane.

(ANS-Me), mandibular molar height (Mic-ML), occlusal plane angle (OL-NSL), and mandibular plane angle (ML-NSL), with a concomitant decrease in overbite (Ii-OL) when treatment (T_2-T_1) was compared with control (T_1-T_0) periods.

Comparison of Control Period (T_0 to T_1) Between the Two Age Groups

Fig. 5 compares the sagittal and vertical changes between the two age groups during the control period (T_0 to T_1). No significant difference was found in either maxillary or mandibular growth changes during the control period. The maxilla grew 0.2 mm in the younger group, 0.1 mm in the older group, and downward 0.3 mm in the younger group, 0.8 mm in the older group. The mandible grew forward 1.0 mm in the younger group, 0.9 mm in the older group, and downward 0.2 mm in the younger group and 0.5 mm in the older group. Dental movement was also similar in both age groups. Significant difference between the two groups was found only in the anterior movement of the mandibular first molar (1.0 mm in the younger age group vs. 0.4 mm in the older group.)

Table II. Descriptive statistics for sagittal cephalometric measurements with comparisons between treatment and control time periods

Sagittal cephalometric measurements	Younger age group (<8 years old)			Older age group (>8 years old)		
	T_0	T_1	T_2	T_0	T_1	T_2
Skeletal changes						
Maxillary base (mm) A-OLp	69.4 ± 2.7	69.6 ± 2.6	71.5 ± 3.0***	68.5 ± 3.7	68.6 ± 3.7	70.7 ± 3.7***
Mandibular base (mm) Pg-OLp	78.9 ± 4.0	79.9 ± 3.9	78.6 ± 3.6***	78.5 ± 4.1	79.4 ± 4.8	77.5 ± 3.9***
Dental changes						
Maxillary incisor (mm) Is-OLp	75.5 ± 2.7	76.6 ± 3.2	81.2 ± 3.7***	75.9 ± 4.0	76.3 ± 4.3	80.1 ± 3.2***
Mandibular incisor (mm) Ii-OLp	77.9 ± 3.1	78.4 ± 3.4	77.0 ± 2.9**	78.3 ± 3.9	79.0 ± 3.9	76.3 ± 3.5**
Maxillary molar (mm) Ms-OLp	46.6 ± 3.1	47.2 ± 3.0	51.3 ± 4.0***	47.5 ± 4.4	47.8 ± 4.6	51.4 ± 3.8***
Mandibular molar (mm) Mi-OLp	49.9 ± 3.4	50.9 ± 3.4	50.7 ± 3.5**	51.5 ± 4.7	52.0 ± 5.0	51.2 ± 3.8**
Overjet (mm) Is-OLp minus Ii-OLp	−2.4 ± 1.4	−1.9 ± 1.6	4.2 ± 2.4***	−2.4 ± 1.1	−2.7 ± 1.9	3.9 ± 2.0***
Molar relation (mm) Ms-OLp minus Mi-OLp	−3.3 ± 2.4	−3.6 ± 2.2	0.6 ± 1.6***	−4.0 ± 2.1	−4.2 ± 2.6	0.1 ± 1.7***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
p values at T_2 refer to tests for significant differences between treatment (T_1 to T_2) and control (T_0 to T_1) time periods.

Table III. Descriptive statistics for vertical cephalometric measurements with comparisons between treatment and control time periods

Sagittal cephalometric measurements	Younger age group (<8 years old)			Older age group (>8 years old)		
	T_0	T_1	T_2	T_0	T_1	T_2
Skeletal changes						
Maxillary base (mm) A-OL	24.3 ± 4.7	24.5 ± 4.6	25.1 ± 5.6	30.5 ± 6.0	31.3 ± 5.6	31.6 ± 5.4
Lower facial height (mm) ANS-Me	58.7 ± 3.1	59.0 ± 2.2	61.3 ± 2.3**	60.4 ± 3.2	61.0 ± 3.2	65.0 ± 3.6***
Dental changes						
Maxillary incisor (mm) Is-NL	25.0 ± 2.0	25.2 ± 1.9	25.1 ± 1.6	25.1 ± 2.2	26.0 ± 2.4	26.6 ± 2.0
Mandibular incisor (mm) Ii-ML	35.7 ± 2.2	36.2 ± 2.0	37.1 ± 2.1	38.0 ± 2.1	38.4 ± 2.1	39.1 ± 1.7
Maxillary molar (mm) Msc-NL	18.9 ± 2.3	19.3 ± 1.8	20.1 ± 2.2	19.3 ± 1.5	19.5 ± 2.0	21.1 ± 2.1**
Mandibular molar (mm) Mic-ML	28.1 ± 2.2	28.1 ± 1.9	29.4 ± 1.7***	28.1 ± 1.8	28.0 ± 1.7	29.1 ± 2.0*
Overbite (mm) Ii-OL	2.3 ± 2.7	2.5 ± 2.2	0.7 ± 0.8**	2.6 ± 2.2	3.3 ± 2.4	1.0 ± 1.2***
Angular changes						
Mandibular plane (deg) ML-NSL	35.0 ± 3.8	35.0 ± 3.7	36.1 ± 3.8*	35.2 ± 3.5	35.0 ± 3.5	36.5 ± 4.1*
Nasal plane (deg) NL-NSL	9.8 ± 3.0	9.6 ± 3.1	8.4 ± 2.8	10.4 ± 3.7	10.1 ± 3.6	9.0 ± 3.8
Occlusal plane (deg) OL-NSL	23.3 ± 3.6	23.2 ± 3.6	21.0 ± 3.6*	22.3 ± 4.2	22.5 ± 4.2	20.4 ± 4.1**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
p values at T_2 refer to tests for significant differences between treatment (T_1 to T_2) and control (T_0 to T_1) time periods.

Comparison of Treatment Effects (T_1 to T_2) Between the Two Age Groups

Fig. 6 compares the sagittal changes between the two age groups during the treatment period and their contributions to overjet corrections. No significant differences were found in maxillary movement, maxillary incisal movement, mandibular movement, maxillary and mandibular molar movements be-

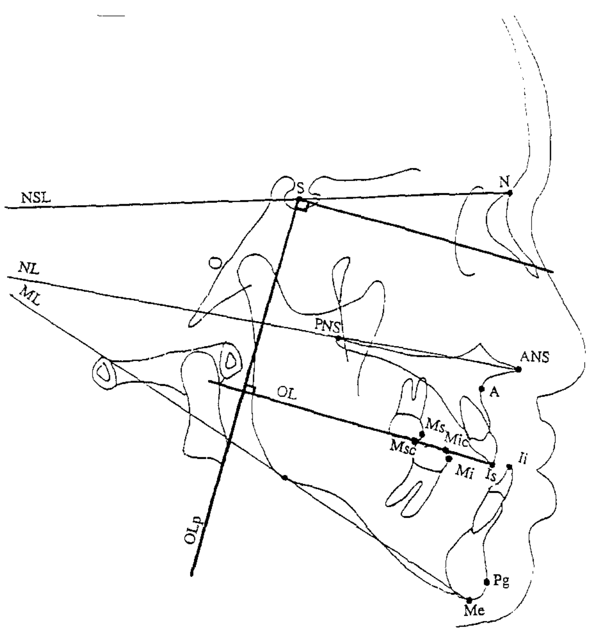


Fig. 4. Cephalometric landmarks and construction lines for cephalometric measurements according to Pancherz.[8]

tween the two age groups. The only significant differences was the lingual movement of mandibular incisors. (1.4 mm vs. 2.7 mm, $p < 0.01$).

The skeletal and dental contributions to overjet correction were slightly different in the two groups. In general, 52% of overjet change was contributed by skeletal change in the younger age group and 63% in the older group because of a larger backward movement in the latter group. The dental contribution in the older group was less than the younger group (37% vs. 48%) because of a smaller forward movement of maxillary incisors in the older group.

The comparison of vertical treatment changes between the younger and older age groups is shown in Fig. 7. During treatment, significantly greater maxillary molar extrusion was found in the older age group (1.7 mm vs. 0.8 mm, $p < 0.05$). The older group also showed a significantly greater increase in lower facial height than the younger group (4.1 mm vs. 2.4 mm, $p < 0.01$).

DISCUSSION

Both conventional cephalometric measurements and the method by Pancherz[8,9] were used in the current study to describe cephalometric changes with growth and development. Most clinicians are familiar with angular measurements such as the SNA, SNB, and ANB angles. However, previous studies have shown that sagittal measurements that used S-N line as a reference are inherently inaccurate, because the form of location of sella turcica and nasion have been shown to vary with growth.[11-14] The use of a construction grid eliminates the need for the reference line. The occlusal line (OL) was chosen because it is closest to most of the landmarks measured. The accuracy of cephalometric landmarks used in the current study had been investigated on the skulls that originated in southern China.[15] A series of cephalograms were taken with reference steel ball markers glued on the skulls to represent the "true" skeletal and dental landmarks. The accuracy of locating the sagittal and vertical landmarks with or without the use of the steel ball markers was compared, and no significant differences were found between the two series of cephalograms.

The pretreatment structure of the two age groups are quite comparable, except for the slightly larger linear measurements in the older group. Both age groups presented with a reverse overjet and a negative (Class III) molar relationship before treatment.

Within 6 months of maxillary protraction and expansion, forward movement of maxilla in both groups was accompanied by labial movement of incisors and increase in vertical measurements. Maxillary molar extrusion resulted in increased lower face height, increased mandibular plane angle, and posterior movement of mandible. In both groups, sagittal correction of Class III malocclusion was primarily a result of forward movement of the maxilla and clockwise rotation of the mandible. Overjet correction was contributed by both skeletal and dental changes in both age groups. These findings are in accordance with previous studies.[1,7,16-19]

Growth rate between the two age groups can be compared by measuring the cephalometric changes (T_1-T_0) before treatment. Maxillary and mandibular growth rates were not statistically different between the younger and older age groups. In both groups, maxillary and mandibular growth was forward and downward, with mandibular growth exceeding maxillary growth. These data suggest comparable amounts of jaw growth in both younger and older age groups during a 6-month period. Dental changes during this period were found to be similar in both age groups. Significant difference was found only in mesial movement of the mandibular first molar, which was greater in the younger age group. This is unusual because greater mesial movement is expected in the late rather than early mixed dentition, with the loss of deciduous molars and closure of

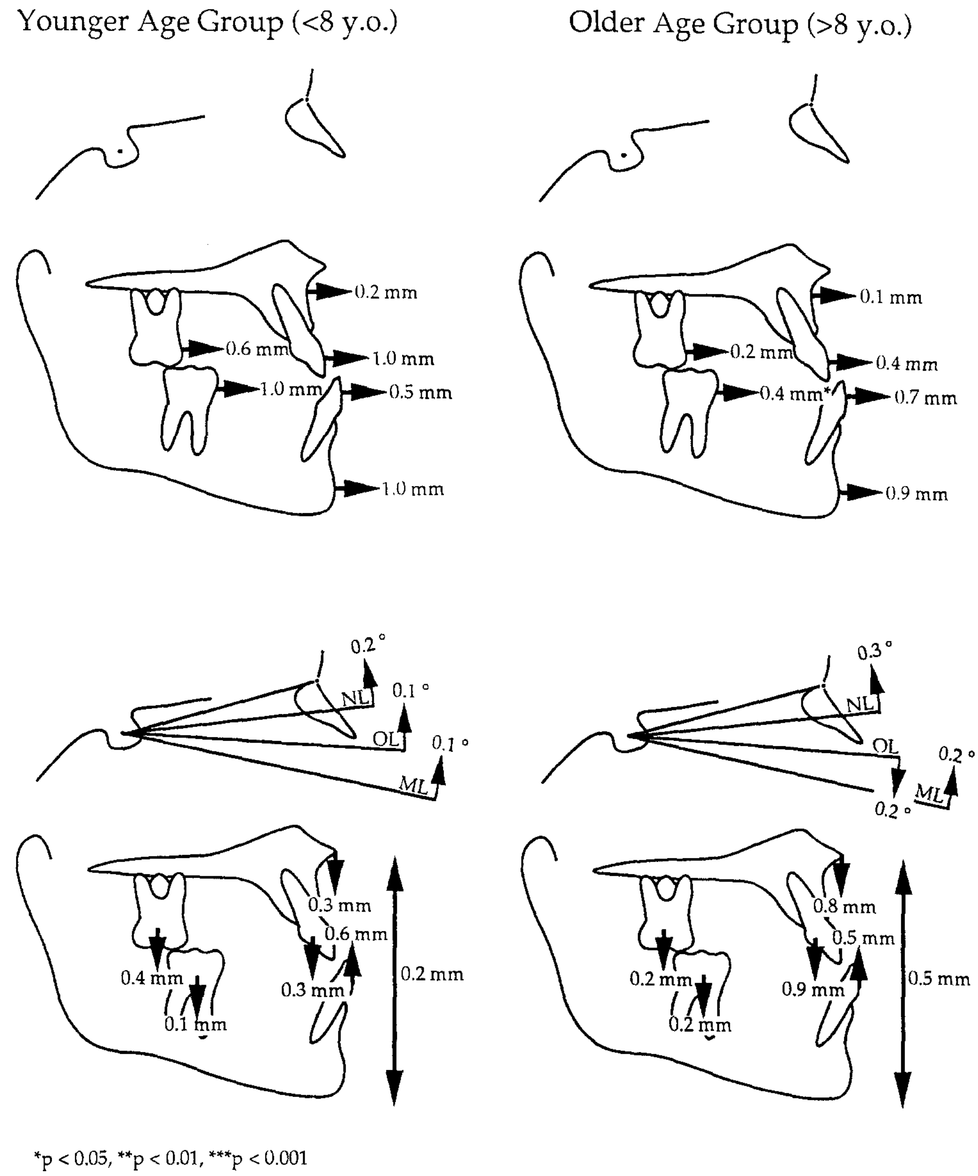
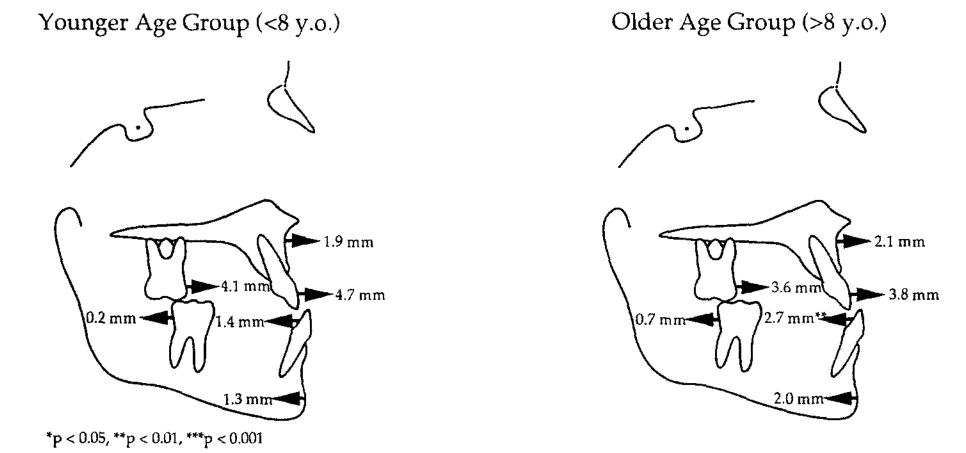


Fig. 5. Schematic illustration of mean changes during control period with comparisons between two age groups.

leeway space. A possible explanation for this finding could be that there was a greater forward drift of the lower molar during the development of an anterior crossbite in the younger age group.

Cephalometric changes during the treatment period were strikingly similar between the two age groups. Nearly equal overjet correction occurred in both groups. Overjet correction was achieved by 52% skeletal movement and 48% incisor tipping in the younger group and 63% skeletal movement and 37% incisor tipping in the older group. Maxillary and mandibular skeletal changes were very similar for the two age groups. These data suggest that similar skeletal response can be expected in both the early (5 to 8 years old) and late (8 to 12 years old) mixed dentition with the use of reverse-pull headgear in combination with rapid maxillary expansion. However, a difference was found in vertical response between the two age groups. During treatment, maxillary molar extrusion was greater in the older age group (1.7 vs. 0.8 mm) along with a greater increase in lower facial height (4.1 vs. 2.4 mm). This effect may be contraindicated in patients with vertical growth pattern. A bonded expansion appliance



Younger Age Group (<8 y.o.)

Overjet correction	6.1 mm (100%)
skeletal contribution	
maxilla	1.9 mm (31%)
mandible	1.3 mm (21%)
dental contribution	
maxillary	2.8 mm (46%)
mandibular	0.1 mm (2%)

Older Age Group (>8 y.o.)

Overjet correction	6.5 mm (100%)
skeletal contribution	
maxilla	2.1 mm (32%)
mandible	2.0 mm (31%)
dental contribution	
maxillary	1.7 mm (26%)
mandibular	0.7 mm (11%)

Fig. 6. Schematic illustration of mean changes in sagittal dimensions during treatment with comparisons between two age groups.

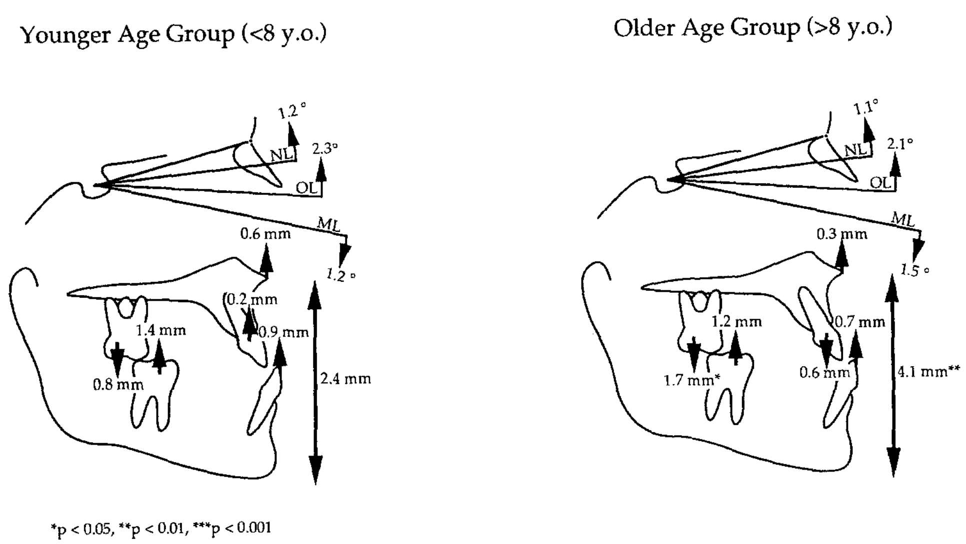


Fig. 7. Schematic illustration of mean changes in vertical dimensions during treatment with comparisons between two age groups.

with a posterior bite-block may be used instead of a banded expansion appliance.[20]

The results of this study may help in revising the current clinical recommendations[4-6] for treatment of maxillary deficiency. Our data show that treatment of maxillary deficiency with reverse-pull headgear and rapid palatal expansion may be effective in younger (5 to 8 years old) and older (9 to 12 years old) patients. Apparently, circumpubertal maxillary deficient growth patterns can be intercepted and altered to produce responses similar to those seen in early childhood. These findings are in agreement with Takada and associates,[7] who demonstrated very similar therapeutic results between prepubertal (ages 6.3 to 9.3 years) and midpubertal (ages 8.6 to 11.4 years) female patients who were treated with reverse-pull headgear in combination with chincup forces. Readers should be cautious, this study does not consider the effects of maxillary protraction on patients who are over 12 years old. Data from Takada and coworkers[7] suggest that this mode of therapy does not produce significant orthopedic results in postpubertal age ranges.

CONCLUSIONS

The current study investigated whether there were a greater orthopedic effect and less dental movement when Class III malocclusion was treated with maxillary expansion and protraction before and after 8 years of age in the mixed dentition. Results indicated strikingly similar therapeutic response between the younger and the older age groups. These data suggest that similar skeletal response can be obtained when maxillary protraction was initiated either before age 8 years (5 to 8 years) or after age 8 years (8 to 12 years).

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