Vertical changes in class III patients after maxillary protraction with expansion in the primary and mixed dentitions

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Abstract

Purpose: This study determined the vertical response of class III patients in the primary, mixed, and late mixed dentition phases fitted with a protraction mask and expansion.

Methods: The before and after cephalometric records of 112 patients divided by sex were analyzed at ages 3 to 6, >6 to 9 and >9 to 12 years to assess the vertical changes. Data was correlated by means of paired t tests and scheffe´s multiple contrasts. The study showed: (1) descriptive statistics and the before and after results in males and females in the different age groups; (2) the changes in males and females disregarding age; and (3) the changes at the different ages disregarding gender.

Results: The main vertical changes in this study were seen in the FMA angle, GoGn to SN, Facial axis, and ANS-Me between the ages of 3 to 6 years. Between 6 to 9 years, a lesser significant opening existed and no significant change could be seen in the GoGn- SN angular measurement . Between 9 to 12 years all linear and angular measurements became non significant with the exception of ANS-Me.

Conclusions: Class III corrections should be started as early as possible, once the diagnosis is made and cooperation allows it. Most of the changes were seen between the ages of 3 to 6 years. No significance was seen after the age of 9 years with the exception of ANS-Me in both males and females ($P<0.05$). No differences were seen between males and females in all measurements at the different ages with the exception of occlusal plane to SN ($P<0.05$) between 3 to 6 years. The vertical changes were mostly seen in the mandible with no direct benefit from the changes in the midfacial region. (Pediatr Dent 23:125-130, 2001)

Class III malocclusion has received a renovated attention after some misconceptions which included the idea that the genetic predetermined growth potential could not be altered, commiting the patient to dental camouflage or orthognatic surgery. The application of an orthopedic force to the mandible was introduced. For a long time the use of the chincup was recommmended with the hope that pressure applied to the mandible would restrict and redirect mandibular growth.[1-4] Results generally showed some mandibular rotation which allowed to correct in part the overjet relationship . These changes were greater at early ages, indicating that chincups were more effective before the pubertal growth spurt. However, several authors showed that this type of therapy hardly altered the inherited prognathic characteristics during puberty and a return to pretreatment conditions was common.[3,5,6]

After these failures, protraction masks have shown an interesting combined approach of skeletal maxillary advancement and mandibular rotation.

The effects of maxillary protraction therapy in the craniofacial skeleton has been analyzed on a clinical,[7-20, 26-28] experimental,[21-23] and biomechanical basis.[24,25]
The main changes reported from these studies include the following responses:

1. Changes in the maxilla: maxillary skeletal protrusion, downward movement of the maxilla. Also, depending on the nature of the study, some authors found a counter clockwise rotation of the maxilla, while others reported an anterior maxillary rotation as a result of a downward movement of the nasal spine.
2. Changes in the mandible: mandibular posterior clockwise rotation, increased anterior face height, and increased facial convexity. Most of the changes are attributed to the downward growth of the maxilla.
3. Tooth changes: proinclination of maxillary teeth, retroinclination of mandibular teeth and molar extrusion. Animal studies also showed remodeling in all

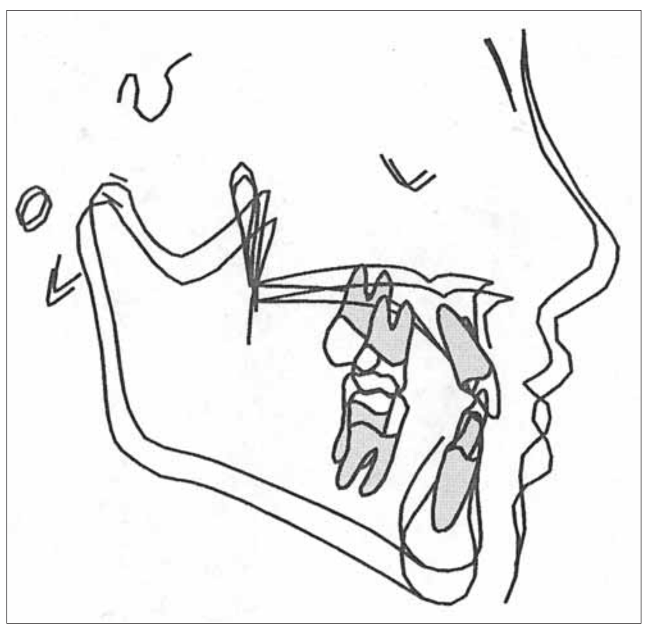

Fig 1. Composite response of skeletal and dental changes following protraction mask therapy on an 8 year old boy.

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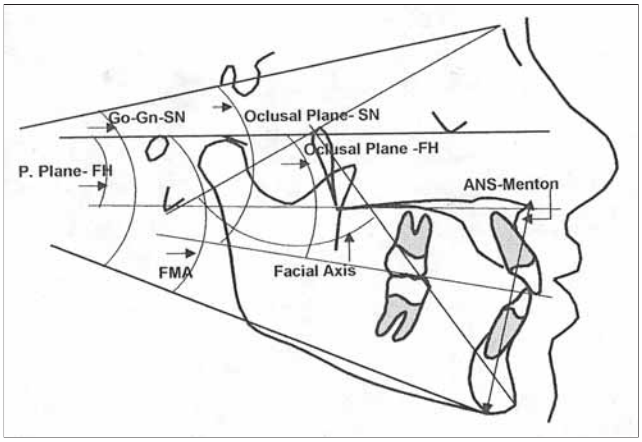

Fig 2. Vertical linear and angular measurements used in this study.

circummaxillary sutures. The amount of remodeling was proportional to the suture's distance from the protraction mask and the orientation of the force system.

The effects of mandibular rotation and the increased vertical from the chin support attachment seen in chincup patients and protraction masks patients is well documented and helps in part in the correction of the overjet relationship and the improvement of the patient´s skeletal profile. [7-20,26-28]

A review by Kim and co-authors[27] summarizes the vertical effects from the combination of the following skeletal changes: "The maxilla is displaced downward with a downward movement of the posterior palatal plane. Posterior teeth extrude. As a consequence, the mandible rotates downward and backward, this being a major contributing factor in the establishment of a positive maxillo-mandibular relationship."

Compared to other studies, our previous report[28] did not show any significant changes in the SNB angle, with the exception of males between the ages of 3 to 6 years. For this reason, we decided to analyze the vertical response of maxillary protraction therapy with slow maxillary disjunction in males and females at different ages.

Methods

The material consisted of pretreatment and postreatment lateral cephalograms of 112 patients from a private practice (MS) ages 3 thru 12 and were divided in the following manner:

All patients had been treated with a protraction face mask with transverse skeletal expansion and had no history of craniofacial anomalies, nor undergone prior orthodontic treatment.

	Male	Female	Total
3-6 years	13	25	38
>6-9 years	25	30	55
>9-12 years	7	12	19
Total	45	69	112

Patients wore their facemasks for an average of 6 months between the ages of 3 to 6 years, 9 months for the patients 6 to 9 years and 12 months for patients between 9 and 12 years. They were instructed to wear the protraction mask at bedtime for children under the age of 9 and 14 hours for children over the age of 9 years.

Elastics that delivered approximately 395 gr. (14 oz) of force per side were fitted on all patients who were instructed to change them on a daily basis.

The Hyrax or Hass rapid maxillary expansion appliance was activated 3 times a week, even in the absence of maxillary constriction or a posterior crossbite. Activation depended on the amount of constriction but generally never lasted over two months. In case no constriction and/or crossbite existed, activation was delivered only for a month.

The pretreatment X-ray was generally taken 1 month prior to appliance insertion and post-treatment X-ray after treatment completion, which represented an average of 8 to 14 months in the before and after results depending on the age of the patients.

Treatment was discontinued when an overjet larger to normal (2 to 3 mm), class I or II canine relationships, a mesial step and or edge- to- edge molar relationships, and an improved facial profile were achieved in the primary dentition. In the mixed dentition, treatment was discontinued when a positive overjet was achieved and no more changes were noted after 3 months. No retention appliances were used afterwards.

Criteria for patient selection

All subjects included in this study had to meet criteria in three different domains: 1. dental 2. facial; 3. skeletal.

1. Dental: Patients with mesial step, exaggerated mesial step, class III Angle molar occlusion, or a class I Angle molar occlusion with lingual rotation of maxillary molars, were included. In all cases, care was taken in the assessment of molar occlusion, taking into account, premature tooth loss, interproximal caries or Bolton discrepancies.

Table I. Changes in Cephalometric and L inear Measurements in Vertical Relationships in Males at Different Ages

	3-6 (N=13)			>6-9 (N=25)			>9-12 (N=7)		
	$\bar{X}$±SD before	$\bar{X}$±SD after	*P*-value	$\bar{X}$±SD before	$\bar{X}$±SD after	*P*-value	$\bar{X}$±SD before	$\bar{X}$±SD after	*P*-value
FMA (deg)	25.2±3.7	27.3±4.9	0.01*	24.8±4.0	25.3±4.1	0.17	25.6±6.9	25.9±6.8	0.51
GoGn-SN (deg)	35.2±4.4	37.4±4.9	0.001**	34.8±4.0	35.3±4.0	0.21	37.7±7.0	37.2±6.9	0.57
Palatal plane to FH (deg)	2.7±3.2	4.2±3.7	0.08	3.2±3.2	3.5±2.8	0.62	4.4±5.2	3.8±4.8	0.35
Facial axis (deg)	89.2±4.1	87.3±4.3	0.0006**	89.8±3.1	89.0+3.5	0.02*	88.7+5.4	89.1±5.3	0.06
Oclusal plane to SN (deg)	19.0±2.9	20.3±4.1	0.11	19.3+3.8	20.2±4.2	0.18	20.3+4.0	18.0±3.8	0.13
Oclusal plane to FH (deg)	8.9±2.2	10.2±3.3	0.10	9.3±4.0	10.3+3.8	0.15	8.1+5.0	6.7±6.2	0.4
ANS to mention (mm)	57.9±4.7	62.0+6.6	0.001**	62.6±3.6	65.2+4.3	0.0000†	65.1+5.1	68.0±6.5	0.03*

†P<0.0001 **P<0.001 *P<0.05

Table 2. Changes in Cephalometric and Linear Measurements in Vertical Relationships in Females at Different Ages

	3-6 (n=25)			>6-9 (n=30)			>9-12 (n=12)		
	X̄±SD before	X̄±SD after	*P*-value	X̄±SD before	X̄±SD after	*P*-value	X̄±SD before	X̄±SD after	*P*-value
FMA (deg)	25.4±3.6	26.1±3.8	0.12	25.8±4.0	26.6±3.6	0.05	26.7±3.8	27.7±4.2	0.12
GoGn-SN (deg)	35.5±3.5	36.6±3.6	0.009•	36.5±4.4	36.9+4.1	0.26	37.4±4.3	38.0+5.0	0.2
Palatal plane to FH (deg)	3.3+2.1	3.8+2.3	0.2	4.1+3.3	3.9+3.3	0.76	3.1+3.1	2.6+2.6	0.39
Facial axis (deg)	91.2+3.2	89.6±3.5	0.0001••	89.8±3.1	89.0+3.5	0.03	88.4±2.4	87.8±2.8	0.1
Oclusal plane to SN (deg)	18.3±3.6	17.8±3.1	0.52	20.3±3.8	20.2+3.5	0.82	20.4+2.9	19.1+3.2	0.19
Oclusal plane to FH (deg)	8.3±3.4	7.3±3.5	0.18	9.6±4.0	9.9+3.8	0.67	9.8±3.1	8.7±3.8	0.36
ANS to mention (mm)	55.5±4.1	59.2+4.3	0.0000••	59.5±3.6	62.3+4.3	0.0000••	64.7±3.4	66.7±4.4	0.01•

••$P<0.001$ •$P<0.05$

Canine class III relationships were difficult to assess in the primary and early mixed dentition because of the inclination of the canine slope, which maintains constant contact in most horizontal and vertical growing individuals. However, class III canine relationships were noted in the late mixed dentition, on mandibular prognatisms, on excessively horizontal patients, and unilaterally on mandibular lateral shifts.

Generalized negative overjets or edge- to- edge anterior relationships were considered in this study. Patients with anterior functional shifts were disregarded. During the mixed dentition the diagnosis was reinforced using tooth measurements from the lateral head film. Upper and lower arch morphology were also taken into account.

2. Facial: The evaluation of the facial profile was possibly one of the most important items in the differential diagnosis. It was essentially subjective in nature. Flat or concave profiles, retrusive maxillas, and or prominent mandibles were included. Convex profiles were only included in the presence of an increased lower face height and an increased vertical associated with other skeletal and dental class III characteristics. Strong, or thin and acute chins were also taken into account as well as thin and poorly developed upper lips.

3. Skeletal: Cephalometric values were utilized with the understanding that those measurements for diagnostic purposes are more realistic in older children with a limited value in younger ones. Diagnosis as well as estimates of treatment changes should be interpreted with caution, because of the possibility of an anterior functional shift which can alter both the sagittal and vertical relationships. [27-29]

Appliances used for class III correction

Bands were fitted on second primary molars and cuspids in the primary dentition and on first permanent molars and first primary molars in the mixed dentition. These bands were joined by a heavy wire (0.043 inches) to the palatal plane and a midline Hass or Hyrax rapid maxillary expansion appliance.

An 0.043 inch wire was soldered bilaterally to the buccal aspects of the molar bands and canines or first primary molars and a hook for elastic traction was extended into the canine region. The adjustable Dynamic Protraction facemask[tm] (Petit type) was positioned just below the lower lip to provide a downward and forward pull to the maxilla of 30 degrees to the occlusal plane.

Cephalometric analysis

All x-ray films utilized in the present study were taken in the same cephalostat. Cephalograms were traced on 0.003 in. acetate paper by two researchers and checked for errors. Ten sets of x-rays were measured to detect the reproducibility of measurements. The combined method error did not exceed 0.8 mm and 1.1° for any variable investigated.

Tracings were digitized on a Numonics digitizer, which was connected to an IBM–PC computer. The Joe[tm] computerized program used cephalometric landmarks, which were incorporated from well-known analyses to provide information on vertical variables (Fig.2).

This study analyzed: 1. Changes in cephalometric and linear measurements in vertical relationships in males, females and both at ages 3-6, 6-9, and 9-12; 2. the changes disregarding gender; 3. the changes disregarding age; 4. the changes disregarding gender and age.

Paired *t* tests were used to describe significant changes between pretreatment and posttreatment cephalogram. Scheffe´s multiple contrasts were also used to compare the multiple responses between the different age groups.

Results

Descriptive statistics and before and after results are shown for males (Table 1) and females (Table 2) at ages 3 to 6, 6 to 9, and 9 to 12. The comparison of changes of the differences between males and females at the different ages are shown in Table 3. The changes in males and females disregarding age are shown in Table 4 and the changes of the differences are shown in Table 5. The changes on all patients disregarding age and gender are represented in Table 6. The changes at 3 to 6, 6 to 9 and 9 to 12 years disregarding gender are shown in Table 7.

The major vertical significant changes were seen in the primary dentition Tables 1, 2, 7. These responses were very similar in males and females and were not contributory by changes in the midfacial region. This can be assessed by a non-significant change at all ages in the occlusal plane to SN, occlusal plane to FH and palatal plane to FH angular measurements (Tables 1, 2).

The major significant vertical contributions between 3 to 6 years were seen in the FMA angle ($P<0.05$ in males and not significant in females), Go-Gn to SN ($P<0.001$ in males and $P<0.05$ in females). Facial axis as well as ANS-Me were also

Table 3. Changes in the Differences of Cephalometric and Linear Measurements in Vertical Relationships in Males and Females at Different Ages

	Males 3-6 (N=13)	Females 3-6 (N=25)		Males >6-9 (N=25)	Females >6-9 (N=30)		Males >9-12 (N=7)	Females >9-12 (N=12)	
	X̄ ±SD	X̄ ±SD	*P*-value	X̄ ±SD	X̄ ±SD	*P*-value	X̄ ±SD	X̄ ±SD	*P*-value
FMA (deg)	2.1±2.4	0.6±2.0	0.06	0.5±1.9	0.9±2.4	0.56	0.4±1.5	1.0±2.0	0.52
GoGn-SN (deg)	2.1±1.9	1.12±2.0	0.14	0.4±1.7	0.5±2.3	0.91	-0.5±1.7	0.7±2.0	0.17
Palatal plane to FH (deg)	1.6±3.0	0.5±1.9	0.15	0.2±2.4	-0.2±3.5	0.6	-0.6±1.6	-0.5±1.9	0.87
Facial axis (deg)	-2.0±1.5	-1.6±1.8	0.59	-0.8±1.7	0.8±2.0	0.96	0.4±0.5	-0.6±1.2	0.052
Oclusal plane to SN (deg)	1.3±2.9	-0.5±4.0	0.14	0.9±3.3	-0.1±2.9	0.22	-2.3±3.5	-1.3±3.2	0.53
Oclusal plane to FH (deg)	1.3±2.7	-0.9±3.6	0.05	1.0±3.4	0.3±3.2	0.4	-1.4±4.2	-1.0±3.8	0.84
ANS to mention (mm)	4.1±3.5	3.7±2.3	0.71	2.6±2.1	2.8±2.3	0.71	2.9±2.9	2.1±2.6	0.49

highly significant (P<0.001 in males and P<0.0001 in females). Between the ages of 6 to 9, the only significant increases were seen in the FMA angle (P<0.05 in females), facial axis (P<0.05 in males and females) and ANS-Me (P<0.0001 in males and females). Between the ages of 9 to 12 years the only significant vertical change was ANS-Me (P <0.05 in both groups) (Tables 1, 2).

When comparing the different vertical responses between males and females at the different ages (Table 3), no significant changes were seen with the exception of occlusal plane to FH between 3 to 6 years (P<0.05). This was the result in an increase of this angular measurement in males (Table 1) from 8.9° to 10.21° and a decrease in females (Table 2) from 8.29° to 7.3°. Greater amount of vertical change can be seen in males compared to females between the ages of 3 to 6 years (Table 3). The FMA angle increase between 3 to 6 years was 2.06° in males and 0.64° in females. These measurements tended to decrease in males as age progressed and to increase in females. The same response was also generally true for Go-Gn to SN (Table 3). Even if no significance can be seen in the palatal plane rotation at all ages and between males and females, there is a slight counterclockwise rotation of the maxillary arch, being more important in females (Table 3). This can be seen in the palatal plane to FH, occlusal plane to SN and occlusal plane to FH where negative numbers are recorded. Occlusal plane angulation responded differently in males and females between 3 to 6 years. Females displayed a counterclockwise rotation while males showed a slight clockwise rotation (Tables 1, 2, 3). The anterior facial height (ANS-Me) was the only linear measurement which increased significantly at all times, being more active between the ages of 3 to 9 years.

Discussion

Although the interpretation of the current cephalometric data should be accepted with caution because of the inherent limitations attributed to the age of the patients studied and the technique, as well as a lack of a control class III population, the results suggest that:

The response of the vertical changes observed was more homogeneous in males and females compared to the sagittal responses on the same population reported earlier.[28] The main vertical changes were accomplished in the primary dentition with no significant changes after the age of 9 years. This is in contradiction with earlier studies where significant vertical increases were seen during the mixed dentition,[7,15] late mixed dentition, or early permanent dentition.[9,10,17,19] Takada[10] did not show any significant changes in the mandible and maxilla in his late pubertal group (ages 12 to 15 years). Even if Scheffe´s multiple contrasts show no significance in the treatment response when comparing the 3-6/ 6-9, 3-6/9-12, and 6-9/9-12, age groups, there is no doubt that early intervention in the primary dentition produces a greater significant change than intervening later, which is in accordance to Kapust´s study. [8]

The restrictive force in the chin area in chincup patients and maxillary protraction patients produces a significant mandibular rotation, opening the bite.[8-20] Our previous study,[28] which is in contrast to the other studies, showed no significant SNB angle reduction in males and females between the ages of 3 to 6, 6 to 9, and 9 to 12 years, with the exception of males between 3 to 6 years.

The main vertical changes in this study were seen in the FMA angle, GoGn to SN, Facial axis, and ANS-Me between the ages of 3 to 6 years. Between 6 to 9 years, a lesser significant opening existed and no significant change could be seen in the GoGn-SN angular measurement. Between 9 to 12 years all linear and angular measurements became non significant with the exception of ANS-Me.

In this study, a minor contribution of the maxillary and palatal planes existed in the vertical response. This result contrasts the findings of several authors who cite rotation of the palatal plane observed by Ishii[19] and Takada[10]. This difference could be the result of the appliances used by these authors such as active chin cups with spurs for maxillary protraction. Also, the vertical responses of the maxilla and tooth movement[7,9,11,17] had a direct effect on mandibular rotation.

The vertical responses between males and females at the different ages showed no statistical differences with the exception of occlusal plane to FH between 3 to 6 years.

Class III malocclusion with no treatment will worsen with time. If an early diagnosis is made, correction will be simplified in the amount and intensity of the change needed to achieve the skeletal, dental, and facial objectives. Some authors would find that the primary skeletal change in the correction of a class III malocclusion was the result of an anterior and vertical movement of the maxilla[8] while others demonstrated that the major skeletal contributor was the downward and backward

Table 4. Changes in Cephalometric and L inear Measurements in Vertical Relations in Males and Females Disregarding Ages

	Males (N=45)			Females (N=67)		
	$\bar{X}$±SD before	$\bar{X}$±SD after	*P*-value	$\bar{X}$±SD before	$\bar{X}$±SD after	*P*-value
FMA (deg)	25.0±4.4	26.0±4.8	0.0039	25.8±3.8	26.6±3.8	0.0036•
GoGn-SN (deg)	35.4±4.6	36.2±4.8	0.01•	36.2±4.1	37.0±4.1	0.004•
Palatal plane to FH (deg)	3.3±3.5	3.7±3.4	0.2	3.6±2.9	3.6±2.9	0.99
Facial axis (deg)	89.5±3.7	88.5±4.0	0.0004••	90.1±3.2	9.0±3.4	0.0000†
Oclusal plane to SN (deg)	19.3±3.5	19.9±4.1	0.28	19.6±3.6	19.1±3.4	0.25
Oclusal plane to FH (deg)	9.0±3.7	9.7±4.2	0.16	9.2±3.7	8.7±3.8	0.3
ANS to mention (mm)	61.6±4.8	64.7±5.6	0.0000••	58.9±4.9	61.9±5.0	0.0000†

†*P*<0.0001 ••*P*<0.001 •*P*<0.05

mandibular rotation[17]. Some studies showed impressive linear and angular changes[9-11,14,15,17-19]. However, greater change could mean a greater possibility for relapse.[17] From this data and our previous study[28] we can observe a lesser but more consistent and homogeneous response affecting the different cranio–maxillo-mandibular structures.

Conclusions

1. The most significant vertical changes were seen between the ages of 3 to 6 years.
2. No significant vertical changes were seen in the 9-12 year group with the exception of ANS-Me linear measurement.
3. The major contributors to the vertical increases were the FMA angle, Go-Gn to SN, Facial axis and ANS-Me and had no direct benefit from the changes in the midfacial region.
4. No significant changes were seen between males and females at the different ages, with the exception of the occlusal plane to SN between 3 to 6 years.

References

1. Irie M, Nakamura S. Orthopedic approach to severe skeletal class III malocclusion. Am. J. Orthod. 67: 377-92, 1975.
2. Graber LW. Chincup therapy for mandibular prognatism. Am. J. Orthod. 72: 23-41,1977.
3. Mitani H, Sakamoto T. Chincap force to a growing mandible: Long term clinical reports. Angle Orthod. 54:93-122, 1984.
4. Petrovic A, Stutzmann J, Effects on the rat mandible of a chin-cup type appliance and of partial or complete immobilization, Proc. Finn. Dent. Soc. 87: 85-91, 1991
5. Sugawara J, Asano T, Endo N, Mitani H. Long term effects of chincup therapy on skeletal profile in mandibular prognatism Am. J. orthod Dentofac. Orthop. 97: 127-133, 1990
6. Ritucci R, Nanda R. The effects of chin cap therapy on the growth and development of the cranial base and midface. Am. J. Orthod. 90: 475-83, 1986.
7. Mermigos J, Clemens AF, Andreasen G. Protraction of the maxillofacial complex Am.J.Orthod. Dentofac.Orthop.98: 47-55, 1990.
8. Kapust AJ, Sinclair PM, Turley PK. Cephalometric effects of face mask/expansion in class III children: A comparison of 3 age groups. Am J. Ortho. Dentofac Orthop. 113: 204-12, 1998.
9. Baik HS. Clinical results of the maxillary protraction in Korean Children. Am. J. Orthod. Dentofac. Orthop. 108: 583-592, 1995.
10. Takada K, Petdachai S, Sakuda M. Changes in dentofacial morphology in skeletal class III in children treated with a modified maxillary protraction headgear and a chin cup: A longitudinal cephalometric appraisal. Eur. J. Orthod.15: 211-21, 1993.
11. MCNamara JA. An Orthopedic approach to the treatment of class III malocclusion in young patients.J.Clin. Orthod.21: 598-608, 1987.

Table 5. Changes in Differences of Cephalometric and Linear Measurements in Vertical Relationships in Males and Females Disregarding Age

	Males (N=45)	Females (N=67)	
	$\bar{X}$±SD	$\bar{X}$±SD	*P*-value
FMA (deg)	0.9±2.1	0.8±2.2	0.71
GoGn-SN (deg)	0.8±1.9	0.8±0.1	0.95
Palatal plane to FH (deg)	0.5±2.6	0.0±2.7	0.33
Facial axis (deg)	-1.0±1.7	-1.1±1.8	0.73
Oclusal plane to SN (deg)	0.5±3.4	-0.4±3.4	0.12
Oclusal plane to FH (deg)	0.7±3.4	-0.4±3.5	0.12
ANS to mention (mm)	3.1±2.7	3.0±3.4	0.12

Table 6. Changes in Cephalometric and Linear Measurements in Vertical Relationships in all Patients

	3-12 (N=112)		
	$\bar{X}$±SD before	$\bar{X}$±SD after	*P*-value
FMA (deg)	25.5±4.1	26.4±4.2	0.0000†
GoGn-SN (deg)	35.9±4.3	36.7±4.4	0.0001†
Palatal plane to FH (deg)	3.5±3.2	3.7±3.1	0.42
Facial axis (deg)	89.8±3.4	88.8±3.7	0.0001†
Oclusal plane to SN (deg)	19.5±3.6	19.4±3.7	0.84
Oclusal plane to FH (deg)	9.1±3.6	9.1±4.0	0.94
ANS to mention (mm)	60.0±5.0	63.0±5.4	0.0000†

†*P*<0.0001

Table 7. Changes in Cephalometric and Linear Measurements in Vertical Relationships at Different Ages Disregarding Gender

	3-6 (N=38)			>6-9 (N=55)			>9-12 (N=19)		
	X̄ ±SD before	X̄ ±SD after	*P*-value	X̄ ±SD before	X̄±SD after	*P*-value	X̄±SD before	X̄±SD after	*P*-value
FMA (deg)	25.4±3.6	26.5±4.2	0.0037*	25.3±4.0	26.1±3.8	0.018*	26.3±5.0	27.0±5.2	0.08
GoGn-SN (deg)	35.4±3.8	36.9±4.1	0.0001**	35.7+4.3	36.2±4.1	0.1	37.5±5.2	37.7±5.6	0.55
Palatal plane to FH (deg)	3.1±2.5	3.9±3.0	0.02*	3.7±3.3	3.71±3.1	0.99	3.6±3.9	3.0+3.5	0.2
Facial axis (deg)	90.5±3.6	88.9±4.0	0.0000**	89.8±3.1	89.0±3.5	0.001**	88.5±3.6	88.3+3.8	0.34
Oclusal plane to SN (deg)	18.5±3.3	18.7±3.6	0.83	19.8+3.8	20.2±3.8	0.39	20.3±3.3	18.7±3.6	0.039*
Oclusal plane to FH (deg)	8.5±3.0	8.3±3.7	0.71	9.5±4.0	10.1±3.8	0.18	9.2±3.9	8.0±4.8	0.19
ANS to mention (mm)	56.3±4.4	60.1±5.3	0.0000**	60.9±3.9	63.6±4.5	0.0001**	64.8±4.0	67.2±5.1	0.001**

**$P<0.001$ *$P<0.05$

12. Nanda R. Biomechanical and clinical considerations of a modified protraction headgear Am. J.Orthod Dentofac. Orthop. 78: 125-139, 1980.
13. Ngan P, HuAM and Fields, H. Treatment of class III problems begins with differential diagnosis of anterior crossbites. Ped. Dent. 19: 386-395, 1997.
14. Ngan P,Hägg U, Yiu C, Merwin D and Wei SHY. Soft tissue and dentoskeletal profile changes associated with maxillary expansion and protraction headgear treatment. Am J. Orthod Dentofac. Orthop.109: 38-49,1996.
15. Shanker S, Ngan P,Wade D,Beck M,Yiu C, Hägg U and Wei. SHY. Cephalometric A point changes during and after maxillary protraction and expansion.Am.J.Orthod. Dentofac. Orthop.110: 423-30, 1996.
16. Turley P.K. Orthopedic correction of class III malocclusion with palatal expansion and custom protraction headgear. J. Clin. Orthod.22: 314-25, 1988.
17. Chong YH, Ive JC and Artun J. Changes following the use of protraction headgear for early correction of class III malocclusion. Angle Orthod.66: 351-62, 1996.
18. Chen Kf, Lai-Ying So L. Soft tissue profile changes of reverse headgear treatment in Chinese boys with complete unilateral cleft lip and palate. Angle Orthod.68: 31-38, 1997.
19. Ishii H, Morita S,Takeuchi Y,and Nakamura S. Treatment effect of combined maxillary protraction and chincup appliance in severe skeletal class III cases. Am. J.Orthod. Dentofac. Orthop. 92: 304-12, 1987.
20. Delaire J,Verdon P,Lumineau JP Ghega-Negrea A, Talmant J et Boisson M. Quelques résultats des tractions extra-orales à appui fronto-mentonnier dans le traitement orthopédique des malformations maxilo-mandibulaires des classes III et des sequelles osseuses des fentes labio-maxilaires. Rev. Stomat. Paris.73: 633-42, 1972.
21. Jackson GW, Kokich VG, Shapiro PA. Experimental response to anteriorly directed extraoral force in young Macaca *Nemestrina* Am. J.Orthod. 75: 319-33, 1979.
22. Kambara T. Dentofacial changes produced by extraoral forward force in Macaca *Irus* Am.J.Orthod 71: 249-77, 1971.
23. Smalley WM. Shapiro PA, Hohl TH, Kokich VG Bränemark PI. Osteointegrated titanium implants for maxillofacial protraction in monkeys. Am. J. Orthod Dentofac. Orthop.94: 285-95, 1988.
24. Tanne K and Sakuda M. Biomechanical and clinical changes of the craniofacial complex from orthopedic maxillary protraction. Angle Orthod. 61:145-152, 1991.
25. Hata S, Takami I, Nakagawa M, Kamogashira K, Ichikawa K, Matsumoto M and Chaconas SJ. Biomechanical effects of maxillary protraction on the craniofacial complex. Am. J. Orthod Dentofac. Orthop.91: 305-11, 1987.
26. Gallagher RW, Miranda F and Bushang PH. Maxillary protraction: Treatment and posttreatment effects. Am. J. Orthod. Dentofac. Orthop.113: 612-9, 1998.
27. Kim JH, Viana MAG, Graber TM, Omerza FF and Begeole EA. The effectiveness of protraction facemask therapy: A meta-analysis. Am. J. Orthod. Dentofac. Orthop. 115: 675-85, 1999.
28. Saadia M and Torres E. Sagittal changes after maxillary protraction with expansion in the primary, mixed and late mixed dentitions: A longitudinal retrospective study. Am.J. Orthod Dentofac. Orthop.117:669-89,2000.
29. Saadia M and Ahlin J. An atlas of Dentofacial orthopedics for the growing child. Chapter II Diagnosis and treatment planning pp 25-64. ESPAXS publishing, Barcelona 1999.