Original Article

Mandibular Behavior with Slow and Rapid Maxillary Expansion in Skeletal Class II Patients

A Long-Term Study

Roberto M. A. Lima Filho[a]; Antonio Carlos de Oliveira Ruellas[b]

ABSTRACT

Objective: To evaluate anteroposterior and vertical mandibular changes in skeletal Class II patients treated with slow or rapid maxillary expansions at 10-year follow-up.

Materials and Methods: The sample consisted of 70 patients divided into two groups, treated with (1) a cervical headgear (CHG) with expansion of the inner bow or (2) a Haas-type rapid maxillary expansion (RME) appliance in conjunction with CHG (RME-CHG). The CHG group consisted of 40 patients (18 males and 22 females, with an average age of 10.6 years at pretreatment [T_1], 13.6 years at posttreatment [T_2], and 23.6 years at postretention [T_3]), and the RME-CHG group consisted of 30 patients (14 males and 16 females with an average age of 10.4 years at T_1, 14.0 years at T_2, and 24.6 years at T_3).

Results: The profiles of SNB, B-Hor, and Pog-Hor showed significant increases for all treatment phases in both groups. The SN-Go-Gn angle showed no significant decrease from T_1 to T_2 and a significant decrease from T_2 to T_3.

Conclusions: For the entire sample (CHG + RME-CHG) the profile analysis between the phases showed mean increases in B-Ver and Pog-Ver for both phases.

KEY WORDS: Skeletal Class II; Mandibular changes; Maxillary expansion; Long-term

INTRODUCTION

The majority of patients with Class II malocclusions have some sort of skeletal discrepancy, such as mandibular retrognathism, maxillary prognathism, or a combination of these discrepancies.[1] An efficient treatment for these patients includes modifications in skeletal and/or dental relationships in each affected area and the control of vertical dimension and its effects on the mandibular relationship in the anteroposterior plane.[2]

The Kloehn cervical headgear (CHG) is the appliance most frequently used for the correction of Class II malocclusion with maxillary protrusion and a reduced vertical dimension, producing distal displacement of the maxilla inferiorly and posteriorly and increasing the vertical dimension.[3–5] This increase in vertical dimension in Class II patients treated with CHG is controversial in the literature. Many studies show that the mandible rotates backwards and the mandibular plane angle increases with the use of CHG,[6–8] whereas others have found no change in the angle resulting from this treatment.[9–12]

Rapid maxillary expansion (RME) has been a common treatment technique for several types of malocclusion. The effects of RME include the downward and forward movement of the maxilla and the downward and backward movement of the mandible, resulting in an increased vertical dimension. The degeneration of the skeletal pattern in Class II patients after RME has raised the question of whether this increase in the mandibular plane angle is not an aggressive method to correct the transverse dimension, although a tendency for the maxilla and the mandible to return to their original position during the stabilization period has been demonstrated.[13]

Wendling[14] reported that by expanding the maxillary arch, it is possible to release the mandible to move forward, thus creating excellent conditions for the mandible to grow to its full extent, helping in Class II correction. Although there are many reports on max-

[a] Private practice, São José do Rio Preto, SP, Brazil.

[b] Associate Professor, Department of Orthodontics, Universidade Federal do Rio de Janeiro, RJ, Brazil.

Corresponding author: Dr Roberto M. A. Lima Filho, Avenida Alberto Andaló 4025, São José do Rio Preto, SP 15015-000, Brazil (e-mail: robertomario@terra.com.br)

Accepted: August 2006. Submitted: July 2006.

Table 1. Mean Age and Range (Years and Months) of All Studied Patients at Pretreatment (T_1), Posttreatment (T_2), and Postretention (T_3)

	CHG			RPE-CHG		
Phase	n	Mean	Range	n	Mean	Range
T_1	40	10.6	8.10–13.2	30	10.4	7.1–15.0
T_2	40	13.6	11.7–16.4	30	14.0	11.0–17.7
T_3	40	23.6	17.6–33.5	30	24.6	17.1–36.3

illary expansion, no study comparing long-term changes between RME and slow maxillary expansion in skeletal Class II patients were found in the literature. The objective of this study was to evaluate the long-term (10-year follow-up) behavior of anteroposterior and vertical mandibular changes in skeletal Class II patients treated with slow maxillary expansion and RME.

MATERIALS AND METHODS

The sample consisted of 70 patients divided into 2 groups: (1) slow maxillary expansion, using CHG with expanded inner bow, and (2) RME, employing a tissue-borne Haas-type RME appliance in conjunction with CHG (RME-CHG). The patients were selected consecutively from the file records according to the following criteria:

- Skeletal Class II with ANB $\geq$ 5°;
- Treated by nonextraction;
- Similar fixed appliance therapy after obtaining Class I molar relationship;
- Absence of Class II intermaxillary elastics;
- A similar retention protocol at the end of treatment.

The CHG group consisted of 40 patients (18 males and 22 females) and the RME-CHG group consisted of 30 patients (14 males and 16 females). The sample's age characteristics are shown in Table 1.

The extraoral appliance used in this study was a Kloehn CHG recommended to be worn for 12 to 14 hours per day. The force applied for the 70 patients averaged 450 g. The patients were seen monthly, when attention was given to three areas of adjustment: (1) the inner bow was maintained at a 4- to 8-mm expansion; (2) the outer bow was maintained at a 10° to 20° elevation to prevent distal tipping of the molars; and (3) the ends of the inner bow were adjusted to rotate the molars. All banded palatal expanders were manufactured in the same clinic. After cementing the appliance (Figure 1A,A_1), the expansion rate was 2 quarter-turns (0.5 mm) per day until adequate overexpansion had been achieved as determined by clinical observation (Figure 1B,B_1). The RME appliance was left cemented in place for 3–9 months while extraoral traction was applied against the maxilla. After the removal of the expander (Figure 1C,C_1) a loose removable acrylic plate was placed within 48 hours. The patients wore the acrylic plate for a variable amount of time, usually 1 year.

In the lateral cephalometric radiographs, the degree of image distortion was determined using a 100-mm correction ruler adapted to the patient, on the midsagittal plane. Kodak T-Mat™ film (20.3 $\times$ 25.4 cm) was used, placed on the left side of the cephalostat, to avoid image enlargement beyond 8% in relation to the structures.[15]

Cephalometric points were digitized (model AccuGrid XNT A30BL, Numonics Corp, Montgomeryville, PA), according to the Ortho lateral regimen and processed with Dentofacial Planner Plus software, version 2.5b (DentoFacial Software Inc, Toronto, Ontario, Canada).

The angular measurements included SNB (mandibular protrusion) and SN-GoGn (mandibular rotation). A custom analysis was designed with the tools of the Dentofacial Planner Plus. The analysis measured the linear distances (in millimeters) from the mandibular landmarks B point and pogonion (Figure 2). The horizontal reference was a line at 7° to sella-nasion (SN) and was referred to as $SN^{+}7$.[16] The line was used to orient the tracings on the computer screen and the printouts. The vertical reference was established perpendicular to $SN^{+}7$, with its origin in sella.

In order to evaluate the reproducibility of the present research in determining the cephalometric points, preliminary essays were performed, aiming at verifying errors in the method employed. Eleven randomly chosen lateral cephalograms were digitized at predetermined intervals (minimum 2 weeks) between the first and the second. The largest error was 0.8 and the smallest was 0.1.

The hypotheses consisted of verifying through profile analysis the differences in the measurements taken at pretreatment (T_1), posttreatment (T_2), and postretention (T_3) and analyzing whether:

H_{01}: the profiles are parallel;
H_{02}: assuming the profiles are parallel, the profiles are coincident;
H_{03}: assuming the profiles are coincident, the profiles are level.

The data were statistically analyzed by using exploratory analyses for the variables studied in the T_1, T_2, and T_3 phases. In hypotheses H_{01} and H_{02}, Hotellings T^2 test was used, considering the profile of each group. In H_{03}, when H_{01} and H_{02} results were nonsignificant, the F-Snedecor test was applied to the entire sample. When these results were significant, the F-Snedecor test was applied separately for each group.

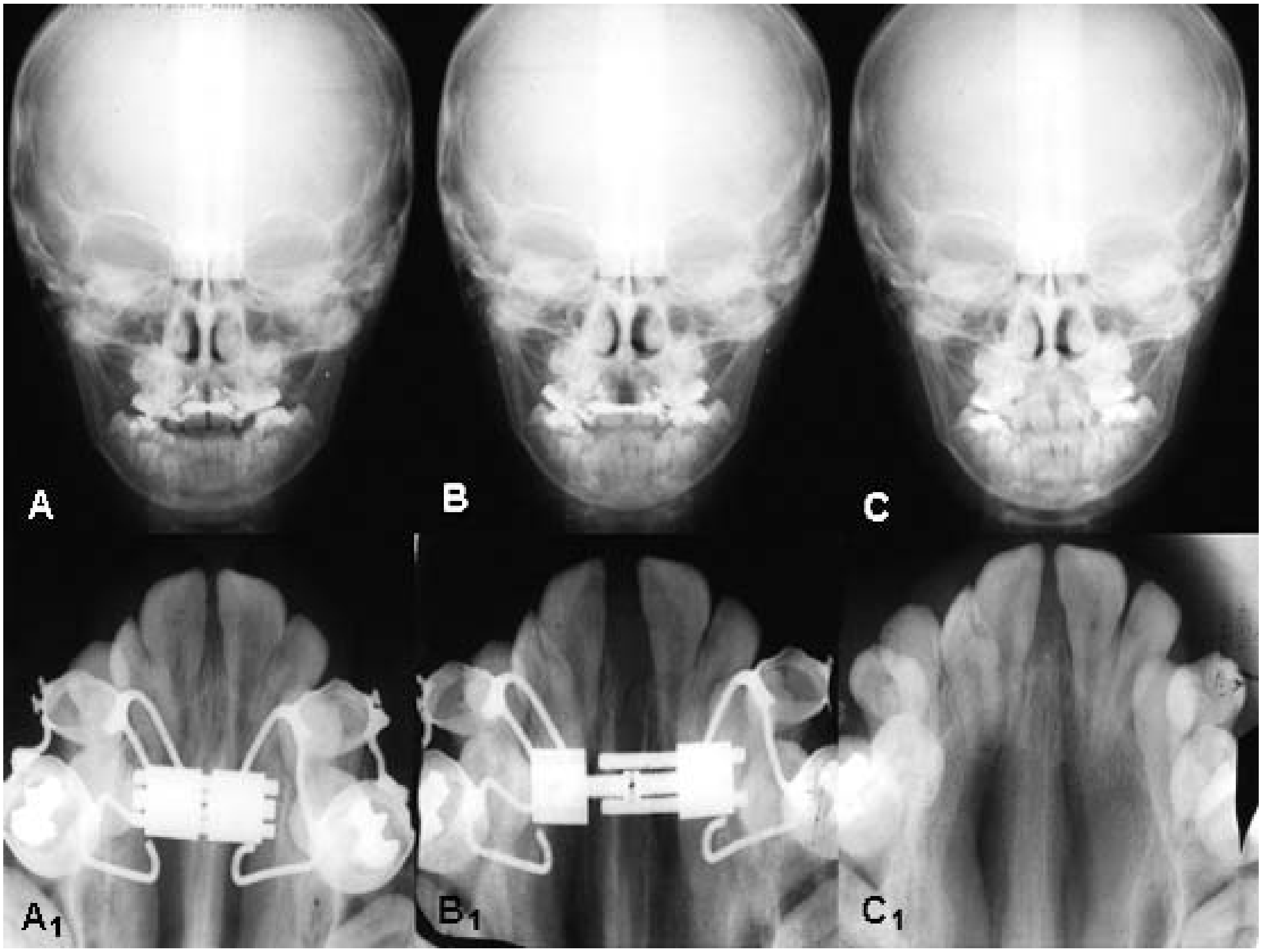

Figure 1. PA cephalograms and occlusal x-rays at pretreatment (A and A_1), postexpansion (B and B_1), and at the time that the maxillary expansion appliance was removed (C and C_1).

The multiple comparisons between phases were tested by the Bonferroni method,[17] considering the differences of phases for paired data.

RESULTS

The results of the descriptive statistics for all measurements in the pretreatment (T_1), posttreatment (T_2), and postretention (T_3) phases in CHG and RME-CHG groups are expressed in Table 2.

According to Hotelling's T^2 test (H_{01}, H_{02}, and H_{03}), the profiles of the SNB and SN-GoGn angles, B point horizontal (B-Hor), and pogonion horizontal (Pog-Hor), showed significant differences at T_1, T_2, and T_3.

Because the H_{01} and H_{02} hypotheses were rejected, a statistical analysis of the profiles between the phases was performed separately for the CHG and RME-CHG groups (Table 3). B point vertical (B-Ver) and pogonion vertical (Pog-Ver) showed no significant differences between the phases in the CHG and RME-CHG groups. For this reason, the F-Snedecor test was applied to the entire sample (Table 3). The profile analysis for SNB, B-Hor, and Pog-Hor showed significant increases in all treatment phases for both groups (Figures 3 through 5). For the SNB angle, the increases from T_1 to T_2 were 0.9° and 1.5° and from T_2 to T_3 they were 1.0° and 0.7° in the CHG and RME-CHG groups, respectively. B-Hor increased 3.8 mm and 4.4 mm from T_1 to T_2 and 2.8 mm and 1.7 mm from T_2 to T_3 in the CHG and RME-CHG groups, respectively. Pog-Hor increased 4.4 mm and 5.2 mm from T_1 to T_2 and 3.5 mm and 2.1 mm from T_2 to T_3 in the CHG and RME-CHG groups, respectively. For the SN-GoGN angle, from T_1 to T_2 the decreases were not significant, with 0.5° and 0.8° in the CHG and RME-CHG groups, respectively, whereas from T_2 to T_3 there were significant reductions of 2.0° and 1.4° in the CHG and RME-CHG groups, respectively (Figure 6).

For the entire sample (CHG + RME-CHG) the pro-

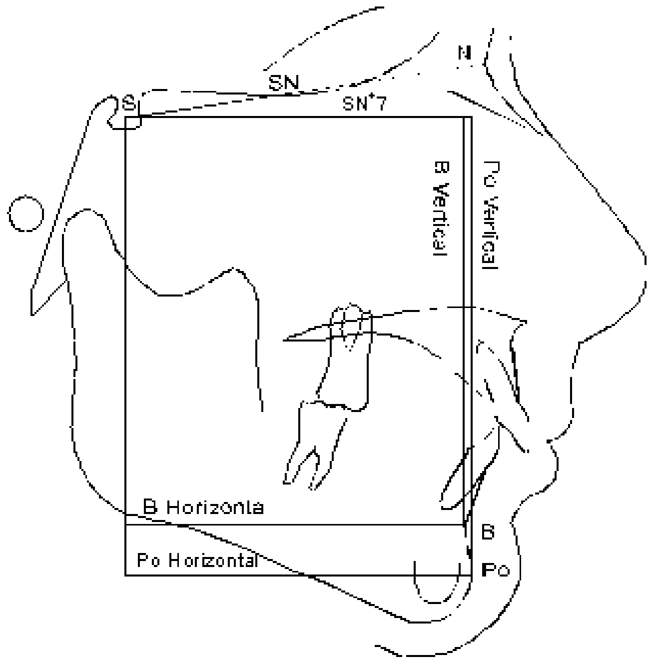

Figure 2. Linear measurements (mm): B-point horizontal to SN+7 perpendicular, B-point vertical to SN+7, pogonion horizontal to SN+7 perpendicular, and pogonion vertical to SN+7.

file analysis between the phases showed significant mean increases of 8.2 mm and 9.6 mm (T_1 to T_2) and of 2.6 mm and 3.0 mm (T_2 to T_3) for B-Ver and Pog-Ver, respectively.

DISCUSSION

Successful treatment of skeletal Class II malocclusion in children is concerned with the adjustments by growth of parts that are out of harmony in their relationships to each other.[18] The profile analysis of the T_1, T_2, and T_3 phases in skeletal Class II patients submitted to slow maxillary expansion and RME showed significant changes between the groups in respect to mandibular protrusion.

The significant increases of SNB, B-Hor, and Pog-Hor between the T_1 and T_2 and between the T_2 and T_3 phases for both CHG and RME-CHG groups indicated a more anterior positioning of the mandible at T_2 and at T_3. These results showed that although all patients were treated with CHG or with RME followed by CHG, the mandible followed its expected normal anteroposterior growth.[19]

Studying the benefits of the treatment in guiding alveolar growth and tooth eruption during mixed dentition, Kloehn[20] achieved Class II correction only with the use of cervical gear. According to this author, if the orthodontist could alter the horizontal growth pattern of the maxilla in Class II patients, the mandible could follow its normal growth until reaching a favorable relationship with the maxilla. However, several studies have revealed that it is possible to promote anterior positioning of the mandible when the maxilla is expanded transversely in subjects with Class II malocclusions.[13,14,21]

Table 2. Descriptive Statistics of Angular (°) and Linear (mm) Measurements Obtained From 40 Patients (CHG Group) and 30 Patients (RME-CHG Group) at Pretreatment (T_1), Posttreatment (T_2), and Postretention (T_3)[a]

		CHG				RME-CHG			
Measure	Phase	Mean	SD	Min	Max	Mean	SD	Min	Max
SNB[b]	T_1	76.7	2.73	71.1	81.1	74.9	3.55	66.6	80.9
	T_2	77.7	3.44	70.0	83.7	76.4	3.63	68.1	82.8
	T_3	78.6	3.07	72.3	84.1	77.1	3.61	69.5	84.4
B-Hor[c]	T_1	62.8	4.38	54.1	72.2	60.3	4.28	53.2	67.3
	T_2	66.6	5.62	52.9	77.7	64.7	5.36	56.7	74.4
	T_3	69.3	5.93	54.9	81.6	66.4	5.58	57.8	77.3
Pog-Hor[c]	T_1	64.4	4.90	54.0	74.7	61.2	4.73	53.2	69.9
	T_2	68.8	6.21	54.4	80.7	66.4	5.75	58.3	79.8
	T_3	72.3	6.86	55.0	86.3	68.5	6.04	59.8	80.7
SN-GoGn[b]	T_1	31.1	4.56	18.7	37.3	35.4	4.67	25.8	44.2
	T_2	30.6	5.38	18.1	40.7	34.6	5.11	22.0	44.0
	T_3	28.5	5.39	15.8	36.5	33.2	5.82	19.0	41.9
B-Ver[c]	T_1	82.8	5.31	71.1	100.6	83.8	4.93	76.4	94.0
	T_2	90.6	6.30	74.9	108.1	92.4	4.41	84.8	101.7
	T_3	93.0	6.35	76.0	109.2	95.2	6.20	82.7	109.6
Pog-Ver[c]	T_1	92.0	6.40	78.3	114.4	92.6	5.23	84.3	104.3
	T_2	101.0	7.39	82.9	117.9	103.0	5.25	95.7	114.7
	T_3	103.9	7.81	86.0	121.6	106.2	6.85	95.7	125.3

[a] SD indicates standard deviation; Min, minimum; and Max, maximum.
[b] Angular measurements.
[c] Linear measurements.

Table 3. Results of Hotelling's T^2, F Test, and *P*-Values for the Hypotheses H_{01}, H_{02} and H_{03}, Mean of Difference (d_{ij}) and Standard Deviation of Difference Between Phases (SD_{ij}), and Confidence Interval for Multiple Comparisons Between Pretreatment (T_1), Posttreatment (T_2) and Postretention (T_3)[a]

	H_{01}		H_{02}		H_{03}					
Measure	T^2	*P*	T^2	*P*	F	*P*	Comparison	d_{ij}	SD_{ij}	CI
SNB	2.47	.30	4.10	.05	—	—	—	—	—	—
SNB[b]	—	—	—	—	34.80	.000+	T_1–T_2	−0.9	1.7	[−1.69; −0.17]
							T_1–T_3	−1.9	2.0	[−2.77; −0.98]
							T_2–T_3	−1.0	1.5	[−1.62; −0.28]
SNB[c]	—	—	—	—	24.23	.000+	T_1–T_2	−1.5	1.8	[−2.29; −0.71]
							T_1–T_3	−2.2	2.4	[−3.21; −1.09]
							T_2–T_3	−0.7	1.2	[−1.19; −0.11]
B-Hor	2.75	.27	4.41	.04	—	—	—	—	—	—
B-Hor[b]	—	—	—	—	84.33	.000+	T_1–T_2	−3.8	3.7	[−5.36; −2.14]
							T_1–T_3	−6.5	4.4	[−8.44; −4.55]
							T_2–T_3	−2.8	3.1	[−4.12; −1.37]
B-Hor[c]	—	—	—	—	48.53	.000+	T_1–T_2	−4.4	3.6	[−6.00; −2.83]
							T_1–T_3	−6.1	4.8	[−8.23; −3.98]
							T_2–T_3	−1.7	2.7	[−2.85; −0.52]
Pog-Hor	3.61	.18	6.06	.02	—	—	—	—	—	—
Pog-Hor[b]	—	—	—	—	107.68	.000+	T_1–T_2	−4.4	3.8	[−6.04; −2.72]
							T_1–T_3	−7.9	4.8	[−9.97; −5.78]
							T_2–T_3	−3.5	3.6	[−5.06; −1.93]
Pog-Hor[c]	—	—	—	—	61.73	.000+	T_1–T_2	−5.2	3.8	[−6.91; −3.55]
							T_1–T_3	−7.4	5.3	[−9.69; −5.01]
							T_2–T_3	−2.1	3.1	[−3.49; −0.74]
SN-GoGn	1.86	.40	13.18	.000	—	—	—	—	—	—
SN-GoGn[b]	—	—	—	—	59.73	.000+	T_1–T_2	0.5	2.2	[−0.44; 1.17]
							T_1–T_3	2.6	2.4	[1.50; 3.61]
							T_2–T_3	2.0	2.0	[1.18; 2.90]
SN-GoGn[c]	—	—	—	—	13.65	.000+	T_1–T_2	0.8	2.1	[−0.13; 1.75]
							T_1–T_3	2.2	3.3	[0.74; 3.66]
							T_2–T_3	1.4	2.2	[0.41; 2.37]
B-Ver	1.26	.46	1.76	.19	490.62	.000+	T_1–T_2	−8.2	3.3	[−9.34; −6.99]
							T_1–T_3	−10.7	4.5	[−12.31; −9.11];
							T_2–T_3	−2.6	3.2	[−3.70; −1.39]
Pog-Ver	2.43	.31	1.21	.28	545.87	.000+	T_1–T_2	−9.6	3.8	[−10.92; −8.23]
							T_1–T_3	−12.6	5.3	[−14.46; −10.70]
							T_2–T_3	−3.0	4.3	[−4.53; −1.47]

[a] $P < .05$ represents a significant difference. .000+ indicates approximately zero; CI, 95% confidence interval of Bonferroni.
[b] CHG group.
[c] CHG-RME group.

All patients studied presented skeletal Class II malocclusion and received maxillary expansion. This may explain the mandibular behavior in the anteroposterior plane, demonstrated by the significant increases of the SNB, B-Hor, and Pog-Hor measurements.

The reduction of 0.5 mm and 0.8 mm in the SN-GoGn angle from T_1 to T_2 in the CHG and RME-CHG groups, respectively, demonstrated that treatment of the skeletal Class II with slow maxillary expansion and RME did not alter the inclination of the mandibular plane angle during treatment. The significant reduction from T_2 to T_3 (at long-term follow-up) indicates that the behavior of this angle was similar to that in untreated patients.[22]

The applied mechanics in slow maxillary expansion (CHG with expanded inner bow) and RME (Haas-type expander) have been associated with an increase in the vertical dimension during orthodontic treatment. Several studies have revealed that the mandible rotates downward and backward and the mandibular plane angle increases with the use of CHG.[23–26] The same effects have been associated with RME because the anterior and inferior movement of the maxilla causes an increase in the mandibular plane angle, resulting in anterior open bite.[27,28]

Although the increase in mandibular plane angle is positive in patients with low mandibular planes and reduced vertical dimensions, these changes may be unfavorable in Class II correction. Schudy[29] pointed out the importance of controlling the vertical dimension in

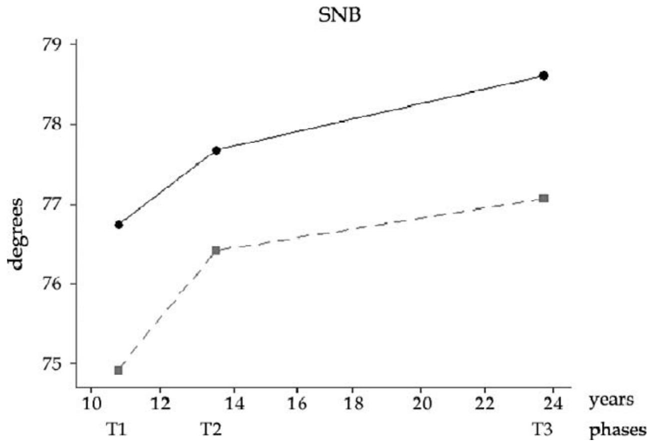

Figure 3. Mean profiles of SNB angle in pretreatment (T_1), posttreatment (T_2), and postretention (T_3) phases. —■— RME-CHG: rapid and slow maxillary expansions; —●— CHG: slow maxillary expansion.

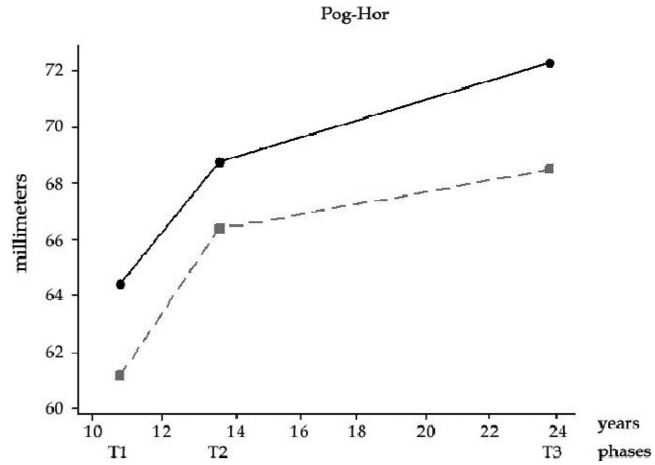

Figure 5. Mean profiles of Pog-Hor in pretreatment (T_1), posttreatment (T_2), and postretention (T_3) phases. —■— RME-CHG: rapid and slow maxillary expansions; —●— CHG: slow maxillary expansion.

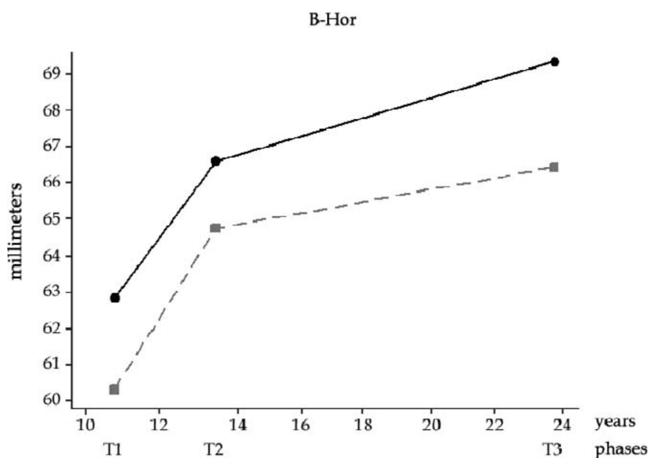

Figure 4. Mean profiles of B-Hor in pretreatment (T_1), posttreatment (T_2), and postretention (T_3) phases. —■— RME-CHG: rapid and slow maxillary expansions; —●— CHG: slow maxillary expansion.

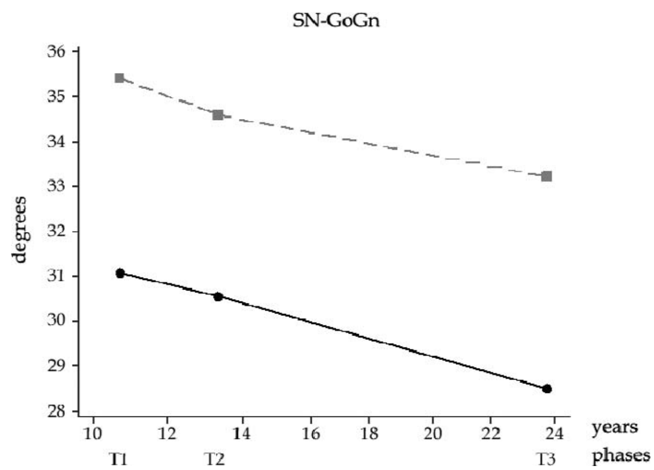

Figure 6. Mean profiles of SN-GoGn angle in pretreatment (T_1), posttreatment (T_2), and postretention (T_3) phases. —■— RME-CHG: rapid and slow maxillary expansions; —●— CHG: slow maxillary expansion.

patients with this type of malocclusion because it can aggravate any preexisting anteroposterior discrepancy.

These negative effects were not observed in the present investigation, possibly because of the treatment protocol and to the favorable growth pattern of the studied patients. All patients used CHG, included those who also used RME. The long outer bow, bent upward, reaching the tragus of the ear or behind the first permanent molars, allowed an excellent control in the anteroposterior and vertical positions of the mandible during Class II correction.

B-Ver and Pog-Ver did not show significant differences between profiles over the treatment phases of both groups. In the total sample, the significant increases from T_1 to T_2 and from T_2 to T_3 indicate a behavior similar to that in untreated patients.[22]

CONCLUSIONS

a. SNB, B-Hor, and Pog-Hor profiles were significantly different throughout the pretreatment, posttreatment, and postretention phases with slow maxillary expansion and RME, showing greater increases during treatment in the RME group.
b. In both groups, no significant changes occurred in the mandibular plane angle during treatment, but significant decreases were detected over the long term.
c. The profiles of B-Ver and Pog-Ver were clinically equivalent in both groups.

REFERENCES

1. Dale J. Interceptive guidance of occlusion with emphasis on diagnosis. In: Graber TM, Vanarsdall RL, eds. *Orthodontics,*

Current Principles and Techniques. 2nd ed. St. Louis, Mo: Mosby; 1994:305–307.
2. Evans CA. Anteroposterior skeletal change: growth modification. *Semin Orthod.* 2000;6:21–32.
3. Poulton DR. The influence of extraoral traction. *Am J Orthod.* 1967;53:8–18.
4. Baumrind SE, Molthen R, West E, Miller DM. Distal displacement of the maxilla and the upper first molar. *Am J Orthod.* 1979;75:630–640.
5. Lima Filho RMA, Lima AL, Ruellas ACO. Longitudinal study of anteroposterior and vertical maxillary changes in skeletal Class II patients treated with Kloehn cervical headgear. *Angle Orthod.* 2003;73:187–193.
6. Merrifield LL, Cross JJ. Directional forces. *Am J Orthod.* 1970;57:435–464.
7. Wieslander L, Buck DI. Physiologic recovery after cervical traction therapy. *Am J Orthod.* 1974;66:294–301.
8. Mays RA. A cephalometric comparison of two types of extraoral appliance used with the edgewise mechanism. *Am J Orthod.* 1969;55:195–196.
9. Cook AH, Sellke TA, Begole EA. Control of the vertical dimension in Class II correction using a cervical headgear and lower utility arch in growing patients. *Am J Orthod Dentofac Orthop.* 1994;106:376–388.
10. Hubbard GW, Nanda RS, Currier GF. A cephalometric evaluation of nonextraction cervical headgear treatment in Class II malocclusions. *Angle Orthod.* 1994;64:359–370.
11. Haas AJ. A biological approach to diagnosis, mechanics and treatment of vertical dysplasia. *Angle Orthod.* 1980;50:279–300.
12. Lima Filho RMA, Lima AL, Ruellas ACO. Mandibular changes in skeletal Class II patients treated with Kloehn cervical headgear. *Am J Orthod Dentofac Orthop.* 2003;124:83–90.
13. Haas AJ. Maxillary expansion: just the beginning of dentofacial orthopedics. *Am J Orthod.* 1970;57:219–255.
14. Wendling LK. *Short-Term Skeletal and Dental Effects of the Acrylic Splint Rapid Maxillary Expansion Appliance* [master's thesis]. Ann Arbor, MI: The University of Michigan; 1997.
15. Thurow RC. Cephalometric method in research and private practice. *Angle Orthod.* 1951;21:104–116.
16. Jacobson R, Sarver DM. The predictability of maxillary repositioning in Le Fort I orthognathic surgery. *Am J Orthod Dentofac Orthop.* 2002;122:142–154.
17. Johnson RA, Wichern DW. *Applied Multivariate Statistical Analysis.* 3rd ed. Englewood Cliffs, NJ: Prentice Hall; 1992.
18. Brodie AG. The fourth dimension in orthodontia. *Angle Orthod.* 1954;24:15–30.
19. Moyers RE, Riolo ML, Guire EK, Wainright RL, Bookstein FL. Differential diagnosis of Class II malocclusions. *Am J Orthod.* 1980;78:477–494.
20. Kloehn SJ. Guiding alveolar growth and eruption of teeth to reduce treatment time and produce a more balanced denture and face. *Angle Orthod.* 1947;17:10–33.
21. McNamara Jr JA, Brudon WL. *Orthodontic and Orthopedic Treatment in the Mixed Dentition.* Ann Arbor, Mich: Needham Press; 1993:86.
22. Riolo ML, Moyers RE, McNamara JA, Hunter WS. *An Atlas of Craniofacial Growth: Cephalometric Standards From the University School Growth Study, the University of Michigan.* Monograph 2, Craniofacial Growth Series. Ann Arbor, Mich: Center for Human Growth and Development, The University of Michigan; 1974.
23. Hanes RA. Bony profile changes resulting from cervical traction compared with those resulting from intermaxillary elastics. *Am J Orthod.* 1959;45:353–364.
24. Barton JJ. High-pull headgear versus cervical traction: a cephalometric comparison. *Am J Orthod.* 1972;62:517–529.
25. Wieslander L, Buck DI. Physiologic recovery after cervical traction therapy. *Am J Orthod.* 1974;66:294–301.
26. Mays RA. A cephalometric comparison of two types of extraoral appliance used with the edgewise mechanism. *Am J Orthod.* 1969;55:195–196.
27. Davis WM, Kronman JH. Anatomical changes induced by splitting of the midpalatal suture. *Angle Orthod.* 1969;39:126–32.
28. Haas AJ. The treatment of the maxillary deficiency by opening the midpalatal suture. *Angle Orthod.* 1965;35:200–217.
29. Schudy FF. Vertical growth versus anteroposterior growth as related to function and treatment. *Angle Orthod.* 1964;34:75–93.