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Effects of a Modified Acrylic Bonded Rapid Maxillary Expansion Appliance and Vertical Chin Cap on Dentofacial Structures

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ABSTRACT

The aim of this study was to determine the sagittal, transverse, and vertical effects of a modified acrylic bonded rapid maxillary expansion (RME) device used with a vertical chin cap on dentofacial structures. The study group consisted of 34 patients (25 girls and 9 boys) who were selected without regard to their skeletal class and gender. All subjects had permanent dentition (mean age, 12.7 years) and needed maxillary expansion. Study Group I (RME only) was composed of 17 subjects, and study Group II (RME with vertical chin cap) was composed of 17 subjects. Twenty-nine measurements were made on the patients' cephalometric films and plaster models. The means and standard deviations for linear and angular cephalometric measurements were analyzed statistically, and intragroup and intergroup changes were evaluated by paired and Student's *t*-tests using SPSS 10.1 for windows. We found that the maxilla moved anteriorly relative to the anterior cranial base. The nasal width, maxillary width, intercanine width, mandibular intermolar width, maxillary intermolar width, and overjet all increased, while the upper molars tipped buccally in both groups. In Group I, the mandible rotated posteriorly, the lower anterior facial height increased, and the overbite decreased. These effects were reduced in Group II. We conclude that the vertical chin cap is an effective appliance for preventing the adverse vertical effects of RME in patients with a crossbite and a vertical growth pattern.

KEY WORDS: Rapid maxillary expansion, Bonded RME appliance, Chin cap.

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INTRODUCTION Return to TOC

Angell[1] first introduced the rapid maxillary expansion (RME) method in 1860. Since that time, different methods and appliances have been introduced.[1–3] The Haas, Hyrax, Minne Expander, Cap Splint, and recently developed acrylic bonded RME appliance are examples of currently used types of RME appliances.

During expansion with conventional RME appliances (Haas, Hyrax, Minne Expander, Cap Splint), bending of alveolar structures and buccal tipping of the posterior maxillary teeth lead to posterior rotation of mandible, open bite, and an increased vertical face dimension.

These effects have a negative effect on facial esthetics.[3–14]

Various RME appliances have been designed to decrease the usual disadvantages of conventional RME appliances. Bonded RME appliances with full occlusal coverage have been reported to have certain advantages over conventional RME appliances.[12,13,15]

Alpern and Yurosko[4] reported the use of full occlusal coverage palatal expansion appliances in patients over 25 years of age. According to the authors, while this appliance limits the vertical effects of interocclusal forces resulting in the release of the maxilla, it also plays an important role in expansion and protraction. They also suggest that this device could provide control of the vertical dimensional changes that occur in vertically growing patients during maxillary expansion.

Aras and Sürücü[16] reported that opening of the bite in patients treated with the Haas-type RME appliance could be controlled with an occlusal-type bite plate. Memikoğlu and İşeri[17] investigated the effects of the Haas-type RME appliance and the rigid acrylic bonded RME appliance. They reported an increase in the tipping of the upper molars and a decrease in overbite in the Haas group as compared with the bonded group.

Investigators have suggested that extraoral appliances can be used in combination with acrylic bonded RME appliances to provide vertical control.[4,5,9,18] Concurrent use of a high-pull headgear or a vertical chin cap has been suggested for patients treated with RME appliances.[6,19–21] Nisco and Nanda[19] and Majourau and Nanda[6] investigated the use of RME together with a high-pull headgear and a high-pull chin cap. They recommended the use of a high-pull chin cap to provide a more ideal force system.

Dipaolo[5] suggested that a vertical chin cap might be used concurrently with RME to reduce the vertical dimension in the posterior region and to significantly improve dental and skeletal open bite. He noted that the application of an intrusive force at the lingual cusps of the posterior maxillary teeth during and immediately after the use of RME offers potential control of both the extrusive and buccal tipping side effects created by the RME.

The aim of our study was to evaluate the sagittal, transverse, and vertical effects of a modified acrylic bonded RME appliance with and without the application of a vertical chin cap on dentofacial structures.

MATERIAL AND METHODS Return to TOC

A total of 34 patients (9 male patients, 25 female patients) treated in the Department of Orthodontics of Selcuk University were included in this study. Lateral and frontal cephalometric films and upper and lower plaster models were obtained before treatment, after treatment, and just after retention.

The patients were selected from a group of patients who had permanent dentition and a crossbite together with maxillary collapse. The patients were selected without any consideration of the their skeletal properties or gender. They were divided into 2 groups: patients in Group I received RME only, and patients in Group II received RME and a vertical chin cap (Dentaurum, Pforzheim, Germany). Each group consisted of 17 patients. Group I consisted of 10 female and 7 male patients, and Group II consisted of 15 female and 2 male patients (Table 1). The modified acrylic bonded RME appliances were used for RME treatment in both groups.

Properties of the appliance and application

A splint type tooth and tissue-borne appliance was used for all patients. The acrylic part of the appliance extended over the occlusal and middle third of the vestibular surfaces of all teeth. The thickness of the occlusal acrylic surface was limited to the freeway space and was in contact with all lower teeth. Holes were opened for the escape of excess cement during cementation. A Hyrax screw was placed in the acrylic plate parallel to the second premolars and as near to the palate as possible. The Hyrax screw (Dentaurum, Pforzheim, Germany) was used to increase the rigidity of the appliance (Figure 1). The appliance was activated with one-fourth turn twice per day in the first week to overcome the resistance of the sutures and once per day after the sutures were mobilized. The vertical chin cap was worn 12 to 16 hours per day with a force level of 250 g per side as recommended by Majourau and Nanda[6] (Figure 2).

In both groups, expansion was considered adequate when the occlusal aspect of the maxillary lingual cusp of upper first molars contacted the occlusal aspect of the facial cusp of the mandibular lower first molars. The 2–3 mm overexpansion was designed to compensate for relapse after expansion. The appliance used in active treatment was cleaned and reused as a removable retention appliance. Retention treatment lasted 12.9 weeks in Group I and 12.1 weeks Group II. At the end of this period, retention measurements were recorded, and orthodontic treatment was continued.

Lateral and frontal cephalometric films and upper and lower plaster models were taken before treatment, after treatment, and after retention. Nine lines were used on the lateral cephalometric films to obtain a total of 21 measurements that included 11 skeletal, 8 dental, and 2 soft tissue measurements. Two lines were used on the frontal cephalometric films to make 2 measurements. Six measurements were obtained from the plaster models. The measurements used in the study are shown in Figures 3 through 5.

Statistical method

Twenty of the 204 lateral and cephalometric films and 20 of the 102 upper and lower plaster models were randomly chosen to calculate the error of the method. Measurements on these materials were repeated after a 1-month interval, and the method error was calculated.[22]

An SPSS statistical package for Windows was used for the evaluation of measurements. The mean differences between the pretreatment and posttreatment measurements, the pretreatment and postretention measurements, and the posttreatment and postretention measurements were evaluated using the paired *t*-test. Student's *t*-test was applied for comparison of the groups.

RESULTS Return to TOC

After 1 month, the measurements and drawings on 20 randomly selected lateral and frontal cephalometric films and plaster models were repeated without knowledge of the first measurements. The error of the method was calculated using Dahlberg's method error formula ($\Sigma d^2/2n$). The values changed from 0.158 to 0.935 and were within acceptable limits.

The pretreatment and posttreatment measurements, the pretreatment and postretention measurements, and the posttreatment and postretention measurements of Groups I and II are summarized in Tables 2, 3, and 4, respectively.

Lateral cephalometrics

Pretreatment vs posttreatment. Differences between pretreatment and posttreatment measurements are shown in Table 2. In Group I, treatment was associated with increases in the mean values for SNA, ANB, SN-MP, and SN⊥U6 (*P* < .001); MP-PP, SV⊥A, and ANS-Me (*P* < .01); and SN⊥PNS and N-ANS (*P* < .05). Treatment was associated with reductions in the mean values for SNB and SV⊥B (*P* < .05). In Group II, treatment was associated with an increase in mean values for ANB (*P* < .001) and SNA and SV⊥A (*P* < .01).

The mean differences between pretreatment and posttreatment values for Group I were compared with those for Group II using Student's *t*-test (Table 2). The difference for Group II was larger than that for Group I for SNB (*P* < .05) but smaller than that for Group I for ANB and SN-MP (*P* < .001), ANS-Me, and SN⊥U6 (*P* < .01) and MP-PP (*P* < .05).

Pretreatment vs postretention. Differences between pretreatment and postretention measurements are shown in Table 3. In Group I, postretention values were greater than pretreatment values for SNA, ANB, SN-MP, and SN⊥U6 (*P* < .001); MP-PP, SV⊥A, and ANS-Me (*P* < .01); and SN⊥PNS and N-ANS (*P* < .05). Postretention values were less than pretreatment values for SNB (*P* < .05). In Group II, postretention values were greater than pretreatment values for SNA and SV⊥A (*P* < .01) and ANB (*P* < .05) but less than pretreatment values for SN-MP (*P* < .01).

The mean differences between pretreatment and postretention values for Group I were compared with those for Group II using Student's *t*-test (Table 3). The mean difference for Group II was larger than that for Group I for SNB and SV⊥B (*P* < .05) but smaller for SN-MP and SN⊥U6 (*P* < .001), ANB and ANS-Me (*P* < .01), and MP-PP (*P* < .05).

Posttreatment vs postretention. Differences between posttreatment and postretention measurements are shown in Table 4. In Group I, postretention values were greater than posttreatment values for SV⊥B (*P* < .01) but less than posttreatment values for ANB and SN-MP (*P* < .01). In Group II, postretention values were greater than posttreatment values for SV⊥B (*P* < .05) but less than posttreatment values for SN-MP (*P* < .05).

Frontal cephalometrics

Pretreatment vs posttreatment. In Group I, the mean posttreatment values were greater than the mean pretreatment values for NC-CN and JL-JR (*P* < .001) (Table 2). In Group II, the posttreatment values were greater than the pretreatment values for NC-CN and JL-JR (*P* < .001) (Table 2).

Pretreatment vs postretention. In Group I, the postretention values were greater than the pretreatment values for NC-CN and JL-JR (*P* < .001) (Table 3). In Group II, the postretention values were greater than the pretreatment values for NC-CN and JL-JR (*P* < .001) (Table 3).

Model evaluations

Pretreatment vs posttreatment. In Group I, the posttreatment values were greater than the pretreatment values for the upper intercanine width, the upper first molar width, the angle between the upper first molars, and overjet (*P* < .001) but less than the pretreatment values for overbite (*P* < .001) (Table 2). In Group II, the posttreatment values were greater than the pretreatment values for the upper intercanine width and the upper first molar width (*P* < .001), the overjet (*P* < .01), and the angle between the upper first molars (*P* < .05) (Table 2).

The mean differences between pretreatment and postretention values for Group I were compared with those for Group II using Student's *t*-test. The mean difference for changes in overbite was larger for Group II than for Group I ($P < .001$) (Table 2).

Pretreatment vs postretention. In Group I, the postretention values were greater than the pretreatment values for the upper intercanine width, the upper first molar width, the angle between the upper first molars, and overjet ($P < .001$) and lower intermolar width ($P < .01$), but less than the pretreatment values for overbite ($P < .001$) (Table 3). In Group II, the postretention values were greater than the pretreatment values for the upper intercanine width and the upper first molar width ($P < .001$) and the lower intermolar width and the angle between upper first molars ($P < .05$) (Table 3).

The mean differences between pretreatment and postretention values for Group I were compared with those for Group II using the Student's *t*-test. The mean difference for changes in overbite was larger for Group II than for Group I ($P < .001$) (Table 3).

Posttreatment vs postretention. In Group I, the postretention values were greater than the posttreatment values for overbite ($P < .01$) but less than the posttreatment values for overjet ($P < .01$) (Table 4). In Group II, the postretention values were greater than the posttreatment values for overbite ($P < .05$) but less than posttreatment values for overjet ($P < .05$) (Table 4).

DISCUSSION Return to TOC

When the clinician evaluates RME results, the problem has always been a question of what factors to consider for preventing open bite and the tendency for relapse.[12] Many investigators have suggested that RME should be done in the prepubertal period or during puberty because skeletal and dental effects are obtained more easily and relapse is rare.[2,9,10,14,18,21,23–27] In our study, the mean ages were 12.8 and 12.6 years for Groups I and II, respectively.

Molar tipping and extrusion have been shown to be the cause of the bite opening and increases in vertical dimensions after conventional RME treatment. Several authors have pointed out that increasing the rigidity of an appliance reduces the rotational component of the forces along the long axis of teeth.[13,26] Therefore, to avoid the tipping of the upper molars and to control the vertical facial dimension, a more rigid type of RME device, namely a modified acrylic bonded RME appliance, was used in the present study. Also many authors have pointed out that the use of a vertical- or oblique-pull chin cap during or immediately after RME is sufficient to prevent the adverse effects and to maintain and control the vertical dimension.[6]

We evaluated the effects on dentofacial structures of a modified acrylic bonded RME appliance used alone and a modified acrylic bonded RME appliance used together with vertical chin cap application.

Lateral cephalometric evaluations

Many investigators have reported that the maxilla moves forward and downward with the use of an RME appliance.[*] However, many other investigators have reported opposite findings.[14,15,24,31–33] We found a significant increase in the SNA angle in both groups. Increases in the measurement of SV⊥A support the concept of anterior movement of the maxilla. The statistically nonsignificant changes at the SNA angle and SV⊥A show the stability of the results after retention.

Many investigators have indicated that a high-pull headgear or a vertical-pull chin cap might be used together with RME to reduce vertical dimension in the posterior region and to significantly improve dental and skeletal open bite. Majourau and Nanda,[6] Nisco and Nanda[19] and Pearson and Pearson[20] noted that the use of high-pull chin cap provides a more ideal force system. Majourau and Nanda[6] found that patients with crossbite did not show the expected vertical adverse effects associated with RME and vertical chin cap therapy on lateral cephalometric superimpositions and in clinical photographs. On the contrary, open bite was reduced, and the anterior overbite was increased by 2 mm after completion of RME.

Haas,[3,10,21] Biederman and Chem,[2] Byrum,[32] Sarver and Johnston,[15] Herold,[34] Ladner and Muhl,[35] Asanza et al,[31] and Timms[30] reported that, as a result of the downward and forward movement of the maxilla with the use of RME, buccal tipping of the upper first molars and extrusion of the palatal cusps cause the mandible to move downward and backward. This movement results in a decreased SNB and an increase in lower face dimensions.

Although vertical chin cap application did not change the position of the mandible in Group II in our study, a statistically significant reduction was noted in the SNB and SV⊥B angles. A statistically significant increase was present at the ANB angle as a result of treatment in both groups. We believe that the increased ANB angle was due to anterior movement of the upper jaw in Group II, whereas it was due to anterior movement of the upper jaw together with posterior rotation of mandible in the Group I. This finding is consistent with findings reported by Aras and Sürücü,[16] Da Silva Filho et al,[24] Erverdi et al,[29] Haas,[21] Memikoğlu et al,[12] and Wertz.[14]

Many investigators have reported that the use of RME results in a downward movement of the maxilla, more at PNS, which results in an increase in the palatal plane angle and upper face dimensions.[†] In our study, increased values were noted for SN⊥PNS and N-ANS in Group I, which is consistent with the findings reported with the use of RME.[‡] On the other hand, in Group II, the vertical position of the maxilla did not change because of the effect of the vertical chin cap. Both dental and skeletal effects on the maxilla during RME produce an undesirable change in mandibular position. The mandible autorotates in a backward and downward direction. This rotation results in an increase in facial convexity and the vertical dimension of the lower face.[6,10,13,19,36]

In Group II, although there was no change in the mandibular plane angle (SN-MP), the maxillomandibular plane angle (MP-PP), the lower face height (ANS-Me), and SN⊥U6 measurements during the expansion period, important increases occurred in Group I. Furthermore, the mandibular plane angle had decreased significantly in Group II at the end of retention.

We believe that increases in the mandibular plane angle, maxillomandibular plane angle, and lower face height as well as decreases in the SNB angle, SV⊥B measurement, resulting from RME and seen in Group I, are due to downward movement of the posterior maxilla together with buccal tipping and extrusion of upper first molars.

In Group II, the mandibular plane angle, maxillomandibular plane angle, lower face height, and SN⊥U6 measurements did not change. Furthermore, the mandibular plane angle decreased significantly after retention. We conclude that good vertical control is obtained with vertical chin cap application.

Frontal cephalometric evaluations

Haas,[21,23] Memikoğlu et al,[12] Memikoğlu and İşeri,[17] Sandıkçıoğlu and Hazar,[37] Wertz,[14] and Wertz and Dreskin[8] have reported increases in the width of the nasal cavity with maxillary expansion. They have also reported that nasal resistance decreases due to expansion of the nasal cavity.[21,30]

A statistically significant increase in nasal width was found in our study in both groups. These findings are consistent with those of investigators reporting increase in the width of the nasal cavity and maxilla with the use of RME.

Model evaluations

Adkins et al,[38] Aras and Sürücü,[16] Erverdi et al,[29] Haas,[10,21] Memikoğlu and İşeri,[17] Reed et al,[33] and Sandıkçıoğlu and Hazar[37] have reported that the distance between the upper canines and upper first molars increases significantly after treatment in both groups. Many investigators have reported increases in the distance between the upper first molars associated with RME.[23,29,36,37,39]

Haas[23] reported the disappearance of vectoral forces on the lower posterior teeth in a lingual direction due to lateral movement of the buccal muscles associated with maxillary expansion. This expansion changes the balance between the tongue and cheek muscles in favor of the tongue. In our study, although we did not observe any changes in the distance between the lower first molars during treatment, we found a statistically significant increase at the end of retention. These findings support the postulate put forward by Haas.[23]

Many investigators have reported that use of RME causes buccal bending of the upper first molars and alveolar structures in varying degrees.[6,7,25,38] Furthermore, after expansion, the upper first molars show a tendency to return to their starting position.[40,41] In our study, we found buccal bending of the upper first molars and alveolar structures. The results obtained did not change after retention treatment.

As a result of the anterior open bite due to buccal tipping of the upper first molars and extrusion of palatal cusps, a downward and backward rotation of the mandible occurs together with increases in overjet.[§]

A significant increase in overjet occurred in both treatment groups in our study. We believe that the increase in overjet was due to anterior movement of the maxilla in Group II and posterior rotation of the mandible together with anterior movement of maxilla in Group I. Many investigators have reported an increase or decrease in overbite.[2,3,14,21,23] In our study, although the amount of overbite did not change with use of the vertical chin cap in Group II, a significant decrease in overbite occurred in Group I during the whole treatment and retention.

CONCLUSIONS Return to TOC

We observed the following changes in our patients:

- The posterior crossbite was corrected in all patients.
- The maxilla moved anteriorly in both groups.
- The width of the nasal cavity increased in both groups.
- The maxillary width increased in both groups.

- The distances between the upper canines, upper first molars, and lower first molars increased in a transverse direction in both groups.
- The upper first molars tipped buccally in both groups.
- The overjet increased in both groups.
- The position of the mandible did not change in Group II, but the mandible rotated downward and backward in Group I.
- The lower face height did not change in Group II, but it increased Group I.
- The posterior of the maxilla and the position of the upper first molars did not change in a vertical direction in Group II, but both moved downwards in Group I.
- The overbite did not change in Group II, but it decreased Group I.

As a result of these findings, we believe that the use of the vertical chin cap during and immediately after RME is sufficient to prevent undesirable side effects and to maintain and control the vertical dimension, especially in patients exhibiting a tendency toward skeletal open bite, a large interlabial gap, or a severe Class II skeletal pattern with a long lower facial height and increased facial convexity.

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TABLE 1. Distribution of Patients in Groups I and II According to Age Expansion Period, and Retention Period

		n	Age, Mean, y	Expansion Period, Mean, wk	Retention Period, Mean, wk
Group I	Boys	7	12.5	5.2	12
	Girls	10	13.1	5.1	12.2
	Total	17	12.8	5.2	12.1
Group II	Boys	2	12.8	6	12.5
	Girls	15	12.6	5.2	13
	Total	17	12.6	5.3	12.9

TABLE 2. Comparisons of Pretreatment and Posttreatment Values Between and Within the Groups

	Group I						
	Pretreatment		Posttreatment		Difference		Test
Measurements	Mean	SD	Mean	SD	Mean	SD	Paired *t*-test
Lateral cephalometric							
1 SNA (deg)	78.09	3.70	79.53	3.15	1.44	1.37	.0005‡
2 SNB (deg)	76.03	2.91	75.29	2.87	−0.74	1.16	.0189*
3 ANB (deg)	2.06	2.32	4.24	1.97	2.18	1.27	.0000‡
4 SN-MP (deg)	39.09	7.26	40.94	7.17	1.85	1.37	.0000‡
5 SN-PP (deg)	9.65	2.66	8.94	2.34	−0.71	1.87	NS
6 MP-PP (mm)	29.50	6.52	30.71	6.60	1.21	1.36	.0021†
7 SN⊥PNS (mm)	46.00	3.39	46.65	3.67	0.65	1.18	.0384*
8 SV⊥A (mm)	50.91	6.54	52.56	6.56	1.65	2.01	.0038†
9 SV⊥B (mm)	38.26	9.58	37.18	10.04	−1.09	1.74	.0204*
10 N-ANS (mm)	55.32	3.25	56.62	3.44	1.29	2.39	.0403*
11 ANS-Me (mm)	68.56	4.63	71.15	5.56	2.59	3.10	.0033†
12 U1P-SN (mm)	103.71	7.28	102.50	6.07	−1.21	3.83	NS
13 L1P-MP (mm)	89.71	4.47	89.56	5.00	−0.15	3.20	NS
14 SN⊥U1 (mm)	83.21	4.27	83.59	4.28	0.38	1.58	NS
15 SN⊥U6 (mm)	68.44	4.39	69.82	4.54	1.38	1.32	.0005‡
16 SV⊥U1 (mm)	51.76	6.94	52.65	7.41	0.88	2.28	NS
17 SV⊥L1 (mm)	48.03	7.30	48.56	8.01	0.53	2.52	NS
18 MP⊥L6 (mm)	27.97	2.02	28.62	2.43	0.65	2.02	NS
19 MP⊥L1 (mm)	40.62	3.16	40.76	3.38	0.15	1.50	NS
20 UL-E (mm)	−3.35	1.52	−3.05	1.90	0.31	0.80	NS
21 LL-E (mm)	−0.53	2.33	−0.22	2.09	0.31	0.62	NS
Frontal cephalometric							
22 NC-CN (mm)	30.53	2.65	34.03	2.73	3.50	1.00	.0000‡
23 JL-JR (mm)	61.53	3.56	66.47	3.24	4.94	1.75	.0000‡
Plaster model							
24 Width between upper canines (mm)	34.23	2.57	40.29	4.38	6.06	2.45	.0000‡
25 Width between upper first molars (mm)	45.01	2.35	51.78	3.07	6.77	2.02	.0000‡
26 Width between lower first molars (mm)	43.00	3.08	43.24	3.15	0.24	0.50	NS
27 Angle between upper first molars (deg)	73.53	9.68	78.59	10.41	5.06	3.77	.0000‡
28 Overjet (mm)	3.62	2.76	4.48	2.76	0.86	0.57	.0000‡
29 Overbite (mm)	2.96	2.08	0.94	2.97	−2.02	1.31	.0000‡

NS indicates nonsignificant.

* $P < .05$, † $P < .01$, ‡ $P < .001$. Significant P values are shown.

*P < .05; †P < .01; ‡P < .001. Significant P values are shown.

TABLE 2. Extended

Group II							
Pretreatment		Posttreatment		Difference		Test	Test
Mean	SD	Mean	SD	Mean	SD	Paired *t*-test	Student's *t*-test
78.68	3.91	79.35	3.75	0.67	0.91	.0080†	NS
76.55	4.17	76.54	3.87	−0.01	0.84	NS	.0455*
2.13	2.21	2.81	2.15	0.68	0.66	.0006‡	.0002‡
40.03	5.09	39.69	4.89	−0.34	0.95	NS	.0000‡
8.26	4.40	7.98	3.98	−0.29	1.25	NS	NS
31.91	6.01	31.91	5.29	0.00	1.22	NS	.0100*
45.47	3.23	45.66	3.22	0.19	0.52	NS	NS
53.56	6.17	54.58	6.31	1.02	1.41	.0088†	NS
41.44	8.56	41.23	8.51	−0.21	1.24	NS	NS
53.21	4.12	53.84	3.58	0.63	1.20	NS	NS
70.56	6.02	70.84	5.73	0.28	0.76	NS	.0055†
103.24	6.99	103.74	7.02	0.50	1.47	NS	NS
89.41	4.89	89.85	4.64	0.44	0.93	NS	NS
82.65	4.57	82.95	4.31	0.30	0.64	NS	NS
69.51	4.60	69.71	4.55	0.19	0.62	NS	.0020†
53.78	7.97	54.36	8.43	0.58	1.16	NS	NS
50.94	7.50	50.88	7.66	−0.06	1.18	NS	NS
27.50	2.03	27.81	2.17	0.31	1.02	NS	NS
39.30	2.50	39.31	2.83	0.01	0.96	NS	NS
−4.12	2.36	−3.61	2.15	0.51	1.01	NS	NS
−1.21	2.32	−0.82	2.28	0.38	1.17	NS	NS
29.29	2.31	32.94	2.05	3.65	1.17	.0000‡	NS
62.12	3.14	67.03	3.05	4.91	2.14	.0000‡	NS
33.21	2.69	38.70	2.80	5.49	1.82	.0000‡	NS
43.60	2.92	49.62	2.35	6.02	2.20	.0000‡	NS
42.42	2.95	42.57	3.03	0.15	0.41	NS	NS
71.47	13.92	75.71	11.78	4.24	6.02	.0104*	NS
2.79	2.70	3.76	2.55	0.96	1.16	.0034†	NS
0.08	3.24	0.15	2.55	0.07	1.09	NS	.0000‡

TABLE 3. Comparisons of Pretreatment and Posttreatment Values Between and Within the Groups§

Measurments	Group I						
	Pretreatment		Posttreatment		Difference		Test
	Mean	SD	Mean	SD	Mean	SD	Paired *t*-test
Lateral cephalometric							
1 SNA (deg)	78.09	3.70	79.41	3.11	1.32	1.13	.0002‡
2 SNB (deg)	76.03	2.91	75.53	2.88	−0.50	0.85	.0271*
3 ANB (deg)	2.06	2.32	3.88	1.95	1.82	1.13	.0000‡
4 SN-MP (deg)	39.09	7.26	40.50	7.18	1.41	1.03	.0000‡
5 SN-PP (deg)	9.65	2.66	9.21	2.38	−0.44	1.66	NS
6 MP-PP (deg)	29.50	6.52	30.68	6.49	1.18	1.40	.0032†
7 SN⊥PNS mm	46.00	3.39	46.35	3.24	0.35	0.68	.0479*
8 SV⊥A mm	50.91	6.54	52.32	6.29	1.41	1.73	.0039†
9 SV⊥B mm	38.26	9.58	37.71	9.83	−0.56	1.26	NS
10 N-ANS (mm)	55.32	3.25	56.32	3.36	1.00	175	.0316*
11 ANS-Me (mm)	68.56	4.63	70.65	5.37	2.09	2.22	.0014†
12 U1P-SN (mm)	103.71	7.28	102.91	6.07	−0.79	2.96	NS
13 L1P-MP (mm)	89.71	4.47	89.41	4.61	−0.29	2.33	NS
14 SN⊥U1 (mm)	83.21	4.27	83.71	4.32	0.50	1.33	NS
15 SN⊥U6 (mm)	68.44	4.39	69.76	4.51	1.32	1.07	.0001‡
16 SV⊥U1 (mm)	51.76	6.94	52.53	7.26	0.76	1.76	NS
17 SV⊥L1 (mm)	48.03	7.30	48.62	7.78	0.59	1.95	NS
18 MP⊥L6 (mm)	27.97	2.02	28.41	2.26	0.44	1.53	NS
19 MP⊥L1 (mm)	40.62	3.16	40.88	4.09	0.26	1.81	NS
20 UL-E (mm)	−3.35	1.52	−3.06	1.58	0.29	0.66	NS
21 LL-E (mm)	−0.53	2.33	−0.35	2.40	0.18	0.43	NS
Frontal cephalometric							
22 NC-CN (mm)	30.53	2.65	33.88	2.53	3.35	0.90	.0000‡
23 JL-JR (mm)	61.53	3.56	66.39	3.24	4.86	1.64	.0000‡
Plaster model							
24 Width between upper canines (mm)	34.23	2.57	40.14	4.42	5.91	2.35	.0000‡
25 Width between upper first molars (mm)	45.01	2.35	51.68	3.08	6.68	1.99	.0000‡
26 Width between lower first molars (mm)	43.00	3.08	43.24	3.08	0.24	0.32	.0083†
27 Angle between upper first molars (deg)	73.53	9.68	78.41	10.34	4.88	3.64	.0000‡
28 Overjet (mm)	3.62	2.76	4.22	2.74	0.60	0.39	.0000‡
29 Overbite (mm)	2.96	2.08	1.56	2.40	−1.40	0.85	.0000‡

§ NS indicates nonsignificant.

* $P < .05$, † $P < .01$, ‡ $P < .001$. Significant P values are shown.

TABLE 3. Extended

Group II							
Pretreatment		Posttreatment		Difference		Test	Test
Mean	SD	Mean	SD	Mean	SD	Paired *t*-test	Student's *t*-test
78.68	3.91	79.64	3.53	0.95	1.06	.0020†	NS
76.55	4.17	76.92	3.84	0.36	1.22	NS	.0226*
2.13	2.21	2.72	1.97	0.59	0.91	.0172*	.0014†
40.03	5.09	39.26	4.76	−0.77	0.93	.0036†	.0000‡
8.26	4.40	7.58	3.89	−0.69	1.56	NS	NS
31.91	6.01	31.97	5.62	0.06	1.25	NS	.0196*
45.47	3.23	45.72	3.31	0.25	0.52	NS	NS
53.56	6.17	54.52	6.17	0.96	1.20	.0046†	NS
41.44	8.56	41.88	8.52	0.44	1.46	NS	.0400*
53.21	4.12	53.50	3.54	0.29	1.20	NS	NS
70.56	6.02	70.55	5.71	−0.01	1.21	NS	.0017†
103.24	6.99	103.83	6.44	0.59	1.82	NS	NS
89.41	4.89	89.50	4.61	0.09	1.15	NS	NS
82.65	4.57	82.98	4.52	0.33	0.77	NS	NS
69.51	4.60	69.45	4.54	−0.06	0.82	NS	.0002‡
53.78	7.97	54.29	8.37	0.52	1.26	NS	NS
50.94	7.50	51.41	7.40	0.47	1.24	NS	NS
27.50	2.03	27.84	2.20	0.34	1.12	NS	NS
39.30	2.50	39.41	3.10	0.11	1.13	NS	NS
−4.12	2.36	−3.71	2.14	0.41	0.83	NS	NS
−1.21	2.32	−0.82	1.78	0.38	1.32	NS	NS
29.29	2.31	32.59	2.11	3.29	1.19	.0000‡	NS
62.12	3.14	67.06	3.09	4.94	1.99	.0000‡	NS
33.21	2.69	38.63	2.84	5.42	1.82	.0000‡	NS
43.60	2.92	49.49	2.43	5.89	2.33	.0000‡	NS
42.42	2.95	42.70	3.16	0.28	0.55	.0491*	NS
71.47	13.92	75.41	11.39	3.94	5.94	.0147*	NS
2.79	2.70	3.23	2.53	0.44	0.96	NS	NS
0.08	3.24	0.51	2.40	0.44	1.05	NS	.0000‡

TABLE 4. Comparisons of Pretreatment and Posttreatment Values Between and Within the Groups§

Measurments	Group I						
	Posttreatment		Postretention		Difference		Test
	Mean	SD	Mean	SD	Mean	SD	Paired *t*-test
Lateral cephalometric							
1 SNA	79.53	3.15	79.41	3.11	−0.12	0.55	NS
2 SNB	75.29	2.87	75.53	2.88	0.24	0.50	NS
3 ANB	4.24	1.97	3.88	1.95	−0.35	0.39	.0017†
4 SN-MP	40.94	7.17	40.50	7.18	−0.44	0.46	.0012†
5 SN-PP	8.94	2.34	9.21	2.38	0.26	1.08	NS
6 MP-PP	30.71	6.60	30.68	6.49	−0.03	0.41	NS
7 SN⊥PNS	46.65	3.67	46.35	3.24	−0.29	0.71	NS
8 SV⊥A	52.56	6.56	52.32	6.29	−0.24	0.73	NS
9 SV⊥B	37.18	10.04	37.71	9.83	0.53	0.67	.0051†
10 N-ANS	56.62	3.44	56.32	3.36	−0.29	1.00	NS
11 ANS-Me	71.15	5.56	70.65	5.37	−0.50	1.13	NS
12 U1P-SN	102.50	6.07	102.91	6.07	0.41	1.62	NS
13 L1P-MP	89.56	5.00	89.41	4.61	−0.15	1.53	NS
14 NS⊥U1	83.59	4.28	83.71	4.32	0.12	1.22	NS
15 SN⊥U6	69.82	4.54	69.76	4.51	−0.06	0.81	NS
16 SV⊥U1	52.65	7.41	52.53	7.26	−0.12	0.72	NS
17 SV⊥L1	48.56	8.01	48.62	7.78	0.06	0.93	NS
18 MP⊥L6	28.62	2.43	28.41	2.26	−0.21	1.15	NS
19 MP⊥L1	40.76	3.38	40.88	4.09	0.12	1.94	NS
20 UL-E	−3.05	1.90	−3.06	1.58	−0.01	0.93	NS
21 LL-E	−0.22	2.09	−0.35	2.40	−0.14	0.59	NS
Frontal cephalometric							
22 NC-CN	34.03	2.73	33.88	2.53	−0.15	0.29	NS
23 JL-JR	66.47	3.24	66.39	3.24	−0.08	0.18	NS
Plaster model							
24 Width between upper canines	40.29	4.38	40.14	4.42	−0.16	0.33	NS
25 Width between upper first molars	51.78	3.07	51.68	3.08	−0.09	0.20	NS
26 Width between lower first molars	43.24	3.15	43.24	3.08	0.00	0.22	NS
27 Angle between upper first molars	78.59	10.41	78.41	10.34	−0.18	0.39	NS
28 Overjet	4.48	2.76	4.22	2.74	−0.26	0.31	.0034†
29 Overbite	0.94	2.97	1.56	2.40	0.62	0.68	.0018†

§ NS indicates nonsignificant.

* $P < .05$, † $P < .01$, ‡ $P < .001$. Significant P values are shown.

TABLE 4. Extended

Group II								
Posttreatment		Postretention		Difference		Test		Test
Mean	SD	Mean	SD	Mean	SD	Paired *t*-test		Student's *t*-test
79.35	3.75	79.64	3.53	0.28	0.83	NS		NS
76.54	3.87	76.92	3.84	0.38	0.78	NS		NS
2.81	2.15	2.72	1.97	−0.09	0.67	NS		NS
39.69	4.89	39.26	4.76	−0.43	0.77	.0350*		NS
7.98	3.98	7.58	3.89	−0.40	1.73	NS		NS
31.91	5.29	31.97	5.62	0.06	0.79	NS		NS
45.66	3.22	45.72	3.31	0.06	0.54	NS		NS
54.58	6.31	54.52	6.17	−0.06	0.73	NS		NS
41.23	8.51	41.88	8.52	0.65	1.17	.0350*		NS
53.84	3.58	53.50	3.54	−0.34	0.71	NS		NS
70.84	5.73	70.55	5.71	−0.29	0.90	NS		NS
103.74	7.02	103.83	6.44	0.09	1.35	NS		NS
89.85	4.64	89.50	4.61	−0.35	0.91	NS		NS
82.95	4.31	82.98	4.52	0.03	0.67	NS		NS
69.71	4.55	69.45	4.54	−0.26	0.58	NS		NS
54.36	8.43	54.29	8.37	−0.06	0.53	NS		NS
50.88	7.66	51.41	7.40	0.53	1.22	NS		NS
27.81	2.17	27.84	2.20	0.03	0.84	NS		NS
39.31	2.83	39.41	3.10	0.11	1.02	NS		NS
−3.61	2.15	−3.71	2.14	−0.10	0.53	NS		NS
−0.82	2.28	−0.82	1.78	0.00	0.98	NS		NS
32.94	2.05	32.59	2.11	−0.35	0.70	NS		NS
67.03	3.05	67.06	3.09	0.03	0.48	NS		NS
38.70	2.80	38.63	2.84	−0.07	0.15	NS		NS
49.62	2.35	49.49	2.43	−0.12	0.31	NS		NS
42.57	3.03	42.70	3.16	0.13	0.37	NS		NS
75.71	11.78	75.41	11.39	−0.29	0.77	NS		NS
3.76	2.55	3.23	2.53	−0.53	0.95	.0362*		NS
0.15	2.55	0.51	2.40	0.36	0.66	.0392*		NS

FIGURES Return to TOC

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FIGURE 1. Modified acrylic bonded rapid maxillary expansion (RME) appliance

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FIGURE 2. Vertical chin cap associated with rapid maxillary expansion (RME) therapy in Group II

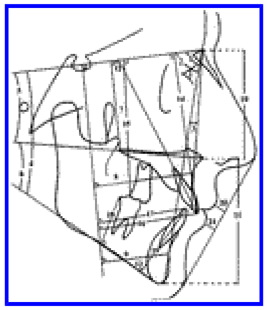

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FIGURE 3. Lateral cephalometric measurements: 1, indicates SNA; 2, SNB; 3, ANB; 4, SN-MP; 5, SN-PP; 6, PP-MP; 7, SN⊥PNS; 8, SV⊥A; 9, SV⊥B; 10, N-ANS; 11, ANS-Me; 12, U1P-SN; 13, L1P-MP; 14, SN⊥U1; 15, SN⊥U6; 16, SV⊥U1; 17, SV⊥L1; 18, MP⊥L1; 19, MP⊥L1; 20, UL-E; and 21, LL-E

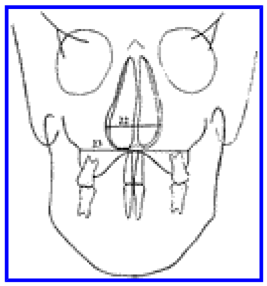

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FIGURE 4. Frontal cephalometric measurements: 22 indicates NC-CN (nasal cavity width); 23, JL-JR (maxillary width)

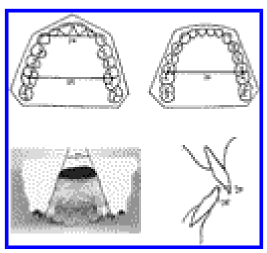

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FIGURE 5. Plaster model measurements: 24 indicates width between upper canines; 25, width between upper first molars; 26, width between lower first molars; 27, angle between upper first molars; 28, overjet; and 29, overbite

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[1] **References 2, 3, 8, 10, 14, 16, 21, 23, 28–30.*

[2] †*References 3, 8, 10, 12, 14, 21, 23, 24, 32, 33.*

[3] ‡*References 3, 8, 10, 14, 21, 23, 24, 32, 33.*

[4] § *References 2, 3, 6, 10, 16, 21, 23, 26, 28.*