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A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures

Sevil Akkaya, Sumru Lorenzon and Tuba Tortop Üçem
Department of Orthodontics, Gazi University, Ankara, Turkey

SUMMARY The purpose of this study was to determine the vertical and sagittal effects of bonded rapid maxillary expansion (RME), and bonded slow maxillary expansion (SME) procedures, and to compare these effects between the groups. Subjects with maxillary bilateral crossbites were selected and two treatment groups with 12 patients in each were constructed. The Hyrax screw in the RME treatment group and the spring of the Minne-Expander in the SME treatment group were embedded in the posterior bite planes, which had a thickness of 1 mm. At the end of active treatment these appliances were worn for retention for an additional 3 months. Lateral cephalometric radiographs were taken at the beginning and end of treatment, and at the end of the retention period.

The maxilla showed anterior displacement in both groups. The mandible significantly rotated downward and backward only in the RME group. The inter-incisal angle and overjet increased in both groups. No significant differences were observed for the net changes between the two groups.

Introduction

There are numerous appliances for the expansion of the dentomaxillary complex with the aim of placing the maxillary dental arch in a stable lateral position. It was generally believed that rapid maxillary expansion procedures result in minimum tooth movement and maximum skeletal displacement. However, it has been reported that slow maxillary expansion procedures produce less tissue resistance in the circum-maxillary structures and improved bone formation in the intermaxillary sutures, and that both factors help minimize post-expansion relapse (Hicks, 1978; Bell, 1982; Mew, 1983).

Haas (1970) noted marked alterations in the direction of growth and in facial morphology as a result of orthopaedic therapy. Several authors have reported that the maxilla is frequently displaced downward and forward during maxillary expansion (Haas, 1961, 1965, 1980; Wertz, 1970; Wertz and Dreskin, 1977; Linder-Aronson and Lindgren, 1979; Gabriel da Silva *et al*., 1991). Isaacson and Murphy (1964) recorded maxillary expansion in cleft patients and observed anterior movement in the maxilla. Cleall (1974) found unfavourable effects in cases with a well positioned maxilla, and in the retention period it has been reported that the maxilla generally returns to its original position. Wertz and Dreskin (1977) found no significant change in the angulation of the palate with rapid palatal expansion. However, Gabriel da Silva *et al*. (1991) reported a downward and backward rotation.

McNamara (1993) stated that widening the maxilla leads to a spontaneous forward posturing of the mandible during the retention period and that a spontaneous correction of Class ll relationship can be found after 6–12 months.

It has been reported that opening of the mid-palatal suture causes downward and backward rotation of the mandible and increased lower facial height as a direct effect of vertical displacement of the maxilla (Haas, 1961, 1965, 1970; Davis and Kronman, 1969; Wertz, 1970; Wertz and Dreskin, 1977; Gabriel da Silva *et al*., 1991). However Hicks (1978) found only minor changes in the position of maxillary implants and in the mandibular plane with slow maxillary expansion procedures. There are also contradictions between authors concerning overbite and overjet changes following maxillary expansion.

Spolyar (1984) stated that the advantages of bonded RME appliances were related to a rotational relocation of the mandibular position. This provided a vertical 'clearing' for simultaneous reduction of anterior crossbite and/or protraction of the maxillary complex (Dellinger, 1973; Haas, 1980; Bishara and Staley, 1987). Also, the imposition of the appliance in the palatal vault caused an increase in the intraoral volume to accommodate a tongue posture that was lower than normal. Sarver and Johnston (1989) believed that the downward and anterior displacement of the maxilla, often associated with the banded rapid palatal expansion appliance, may be negated or minimized with a bonded appliance.

The purpose of this study was to determine the vertical and sagittal effects of bonded rapid maxillary expansion and bonded slow maxillary expansion procedures, and to compare these effects between the groups.

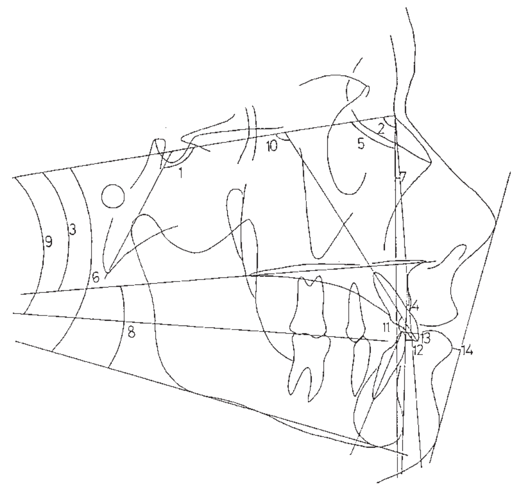

Figure 1 Cephalometric tracing illustrating 11 angular and 3 linear measurements. 1, N–S–Ba; 2, SNA; 3, SN/ANS–PNS; 4, N–Pg–A; 5, SNB; 6, SN/MP; 7, ANB; 8, ANS–PNS/MP; 9, SN/occlusal plane; 10, 1/SN; 11, 1/1; 12, Overjet; 13, Overbite; 14, E plane.

Subjects and methods

The sample included 24 patients with maxillary bilateral crossbites caused by basal apical narrowness, concurrently showing a Class I or II molar relationship.

Two groups were constructed with 12 patients (five girls, seven boys) treated by bonded RME and 12 patients (five girls, seven boys) treated by bonded SME. The mean ages at the initiation of treatment were 11.96 years (10.40–13.50) for the RME group and 12.31 years (9.83–13.50) for the SME group. All patients were matched according to their ANB and mandibular plane angles. The treatment procedures have been described previously (Akkaya *et al*., 1998).

Lateral cephalometric radiographs were taken at the beginning and end of treatment, and at the end of the retention period. Tracings were made with a 0.3-mm pencil. All measurements were read to the nearest 0.5 mm and 0.5 degree. Lateral cephalometric radiographs were evaluated with the 'Quick Ceph' computer program Version 2.6 (Chula Vista Orthodontic Processing, California, USA; Figure 1).

Forty-eight lateral cephalometric radiographs of 24 patients were measured again after 15 days and the measurement error was determined. All measurement error coefficients were found to be close to 1.00 and within acceptable limits (Table 1).

The average differences at the beginning and end of treatment, at the end of treatment and at the end of the retention period, and at the beginning of the treatment and at the end of the retention period were evaluated with a paired *t*-test. A Student's *t*-test was used for comparison of the groups.

Results

Changes in the RME group

SNA, N–Pg–A, SN/MP, ANB, ANS–PNS/MP angles showed significant increases during treatment ($P < 0.001$, $P < 0.01$). Upper incisor/SN angle and overbite decreased significantly in this group ($P < 0.05$, $P < 0.01$). The increases in overjet and E plane measurements as a result of

Table 1 Method error coefficients.

Parameter	*r*
1 N–S–Ba (°)	0.98
2 SNA (°)	0.98
3 SN/ANS–PNS (°)	0.97
4 N–Pg–A (°)	0.99
5 SNB (°)	0.98
6 SN/MP (°)	0.99
7 ANB (°)	0.99
8 ANS–PNS/MP (°)	0.99
9 SN/occlusal plane (°)	0.98
10 1/SN (°)	0.98
11 1′/1̄ (°)	0.95
12 Overjet	0.97
13 Overbite	0.98
14 E plane	0.97

treatment were statistically significant ($P < 0.05$). In the post-treatment period SN/ANS–PNS, upper incisor/SN and E plane measurements showed significant decreases ($P < 0.01$, $P < 0.001$). Significant increases in upper incisor/lower incisor angle and overbite were found during this period in the RME group ($P < 0.01$). The net changes in SNA, N–Pg–A, SNB, SN/MP, ANB, ANS–PNS/MP, upper incisor/SN, upper incisor/lower incisor angle and overjet measurements were found to be statistically significant ($P < 0.05$, $P < 0.01$, $P < 0.001$) (Table 2).

Changes in the SME group

In the SME group SNA, N–Pg–A, ANB, upper incisor/lower incisor angles and overjet showed significant increases during treatment ($P < 0.05$, $P < 0.01$, $P < 0.001$). During the post-treatment period significant decreases were observed in SNA and SN/occlusal plane angles ($P < 0.05$). The net changes observed in SNA, N–Pg–A, ANB, ANS–PNS/MP, SN/occlusal plane, upper incisor/lower incisor angles and overjet were found to be statistically significant ($P < 0.05$, $P < 0.01$; Table 3).

Comparison between the groups

During treatment the increase in upper incisor/lower incisor angle in the SME group was significantly greater than in the RME group ($P < 0.05$). The decrease in overbite in the RME group showed a significant difference compared with the increase in the SME group ($P < 0.001$). The decrease in SN/MP in the RME group showed a significant difference compared with the increase in the SME group throughout the post-treatment period ($P < 0.05$). The decrease in upper incisor/SN angle in the RME group was significantly greater than in the SME group ($P < 0.05$). The increase in overbite in the RME group showed a significant difference compared with the decrease

Table 2 Descriptive statistics and paired *t*-test results in the RME treatment group.

Parameter	Pre-treatment (1)		Post-treatment (2)		Post-retention (3)		*P*		
	$\bar{x}$	S$\bar{x}$	$\bar{x}$	S$\bar{x}$	$\bar{x}$	S$\bar{x}$	1′–2	2′–3	1′–3
1 N–S–Ba (°)	130.52	2.03	130.37	1.98	130.05	2.00			
2 SNA (°)	76.41	0.98	77.40	0.98	77.32	1.05	***		***
3 SN/ANS–PNS (°)	10.66	1.03	10.79	1.11	10.39	1.18		**	
4 N–Pg–A (°)	1.09	0.55	2.71	0.65	2.45	0.72	***		***
5 SNB (°)	74.83	0.93	73.97	0.91	74.19	0.93			*
6 SN/MP (°)	39.40	0.84	41.33	0.99	40.69	0.85	***		**
7 ANB (°)	1.60	0.43	3.42	0.66	3.13	0.60	***		***
8 ANS–PNS/MP (°)	28.73	1.39	30.53	1.55	30.31	1.41	**		***
9 SN/occlusal plane (°)	25.94	1.19	26.85	1.17	25.89	0.97			
10 1/SN (°)	97.03	1.54	96.15	1.41	93.78	1.41	*	***	***
11 1′/1̄	135.87	2.31	136.30	2.12	139.08	2.27		**	**
12 Overjet	2.47	0.60	3.81	0.59	3.07	0.44	*		*
13 Overbite	0.41	0.59	–1.02	0.55	0.11	0.44	**	**	
14 E plane	–1.89	0.78	–0.46	0.79	–2.03	0.76	*	**	

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 3 Descriptive statistics and paired *t*-test results in the SME treatment group.

Parameter	Pretreatment (1)		Post-treatment (2)		Postretention (3)		*P*		
	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	1′–2	2′–3	1′–3
1 N–S–Ba (°)	130.82	1.02	130.99	1.11	131.05	1.06			
2 SNA (°)	75.70	0.77	76.51	0.76	76.24	0.75	***	*	*
3 SN/ANS–PNS (°)	11.42	1.08	11.26	1.05	11.16	1.00			
4 N–Pg–A (°)	–0.06	0.58	0.90	0.73	0.85	0.76	*		*
5 SNB (°)	74.51	0.79	74.21	0.73	75.05	0.79			
6 SN/MP (°)	39.12	1.05	39.75	0.99	40.17	1.06			
7 ANB (°)	1.22	0.37	2.30	0.53	2.20	0.54	**		**
8 ANS–PNS/MP (°)	27.69	1.58	28.50	1.60	29.02	1.66			*
9 SN/occlusal plane (°)	23.63	1.40	22.71	1.15	21.48	1.26		*	*
10 $\underline{1}$/SN (°)	97.88	1.45	96.13	1.07	95.49	1.44			
11 $\underline{1}'/\bar{1}$ (°)	137.15	1.41	140.26	1.27	141.32	1.41	**		**
12 Overjet	2.15	0.55	3.50	0.52	3.55	0.42	**		**
13 Overbite	–0.01	0.43	0.58	0.54	0.35	0.65			
14 E plane	–2.92	0.95	–2.03	1.12	–2.73	1.11			

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

in the SME group ($P < 0.01$). However, there was no significant difference in the net changes between the groups (Table 4).

Discussion

Several authors have stated that anterior movement of the maxilla is significant with RME treatment procedures (Krebs, 1959; Davis and Kronman, 1969; Wertz, 1970; Cleall, 1974; Linder-Aronson and Lindgren, 1979). It has also been shown that the Minne Expander appliance has a sagittal effect on the maxilla (Hicks, 1978; Mossaz and Mossaz-Joëlson, 1989). Gardner and Kronman (1971) stated that opening at spheno-occipital synchondrosis could be responsible for the forward displacement of the maxilla. In this study, SNA angle, as an indicator of the position of the maxilla to the cranial base, showed a significant increase in both groups. Sarver and Johnston (1989) pointed out that anterior movement of the maxilla in the bonded sample was less than in the banded sample. In the post-treatment period the SNA angle tended to decrease in both groups in this study but was statistically significant only in the SME group. It has been reported that after RME treatment the maxilla will partially (Haas, 1970) or completely (Wertz, 1970) return to its original position. Haas (1961) considers that active facial sutures and bones force the maxilla to return to its original position. Mossaz and Mossaz-Joëlson (1989) showed a decrease in the SNA angle with Minne Expander appliance therapy during the retention period. In spite of the relapse during the retention period, the net changes in both groups in this investigation were found to be statistically significant.

The significant increase in the convexity angle (N–Pg–A) in the RME group is in agreement with that found by Haas (1961) and Gabriel da Silva *et al*. (1991). Although there was a significant increase in the SME group, no significant difference was found between the groups. This increase highlights the anterior movement of the maxilla and is in agreement with the increase in SNA and in SN/MP angles. The 1.93-degree increase in the mandibular plane angle (SN/MP) during treatment was found to be statistically significant in the RME group. No significant difference was found in the SME group. Downward movement of the maxilla, and premature contacts between the buccal cusps of the lower and palatal cusps of the upper teeth could be responsible for this increase (Haas, 1965; Wertz, 1970; Wertz and Dreskin, 1977; Sarver and

Table 4 Descriptive statisitics for mean changes and results of the Student's *t*-test indicating significant differences between the RME and SME treatment groups.

Parameter	Treatment change				Post-treatment change				Net change			
	RME group		SME group		RME group		SME group		RME group		SME group	
	$\bar{D}$	S$\bar{D}$	$\bar{D}$	S$\bar{D}$	$\bar{D}$	S$\bar{D}$	$\bar{D}$	S$\bar{D}$	$\bar{D}$	S$\bar{D}$	$\bar{D}$	S$\bar{D}$
1 N–S–Ba (°)	–0.15	0.20	0.17	0.20	–0.31	0.15	0.05	0.22	–0.22	0.30	0.23	0.23
2 SNA (°)	1.03	0.17	0.80	0.16	–0.12	0.12	–0.27	0.09	0.90	0.16	0.53	0.18
3 SN/ANS–PNS (°)	0.13	0.16	–0.15	0.19	–0.40	0.09	–0.10	0.24	–0.26	0.24	–0.25	0.16
4 N–Pg–A (°)	1.62	0.28	0.96	0.35	–0.25	0.22	–0.04	0.19	1.36	0.25	0.92	0.39
5 SNB (°)	–0.58	0.30	–0.30	0.30	–0.05	0.31	–0.16	0.13	–0.64	0.25	–0.46	0.29
6 SN/MP (°)	1.93	0.43	0.63	0.51	–0.64	0.35	0.41	0.25*	1.29	0.33	1.05	0.49
7 ANB (°)	1.60	0.28	1.08	0.31	–0.06	0.26	–0.10	0.16	1.53	0.27	0.97	0.31
8 ANS–PNS/MP (°)	1.78	0.51	0.80	0.54	–0.22	0.30	0.51	0.26	1.56	0.30	1.32	0.45
9 SN/occlusal plane (°)	0.90	0.71	–0.92	0.76	–0.95	0.51	–1.22	0.47	–0.05	0.64	–2.15	0.94
10 1/SN (°)	–0.87	0.29	–1.75	0.85	–2.37	0.43	–0.64	0.69*	–3.25	0.50	–2.39	1.12
11 1′/$\bar{1}$ (°)	0.43	0.77	3.10	0.72*	3.11	0.95	1.05	0.90	3.55	0.84	4.16	1.11
12 Overjet	1.34	0.50	1.35	0.39	–0.74	0.34	0.04	0.21	0.60	0.27	1.40	0.35
13 Overbite	–1.44	0.37	0.63	0.34***	1.14	0.33	–0.30	0.32**	–0.30	0.33	0.33	0.46
14 E plane	1.41	0.63	0.89	0.57	–1.56	0.37	–0.70	2.10	–0.15	0.64	0.19	0.35

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Johnston, 1989). Gabriel da Silva *et al*. (1991) suggested that the increase was as a result of maxillary rotation and molar extrusion caused by buccoversion. Wertz (1970) noted that the increase in mandibular plane angle could be accompanied by a decrease in SNB angle, and Mossaz and Mossaz-Joëlson (1989) reported a tendency to an increase in the mandibular plane angle with the Minne Expander. Hicks (1978), on the contrary, found no significant difference. In this study the addition of acrylic blocks in the appliances was used to eliminate the rotation and extrusion.

The ANB angle increased 1.60 degrees in the RME group and 1.08 degrees in the SME group. These significant increases could be related to the anterior displacement of the maxilla in both groups and the posterior rotation of mandible in the RME group. This is in agreement with Haas (1965) and Wertz (1970). These increases remained significant in both groups at the end of the retention period.

Decreases in 1/SN angle were found to be statistically significant only in the RME group. Both Sarver and Johnston (1989) in their bonded RME group, and Wertz (1970) in his banded RME group showed a posterior tipping of the upper incisors. Opening the overbite by acrylic blocks resulted in a lowered position of the tongue and the stretched circum-oral musculature caused this tipping. A decrease in this degree continued through the retention period. Parallel to these findings, the net changes in the inter-incisal angle showed a significant increase in both groups.

The significant overjet increase found in both groups is in agreement with several authors (Davis and Kronman, 1969; Gardner and Kronman, 1971; Timms *et al*., 1982). However, some authors have found no significant difference in overjet (Hoffer and Walters, 1975; Linder-Aronson and Lindgren, 1979). The overbite decreased in the RME group and this was significantly different compared with the SME group. This could be related to the rotation of the mandible in the RME group. Haas (1961, 1970) reported that occlusal contacts might be responsible for the overbite decrease. In the retention period, a statistically significant increase of 1.14 mm in overbite was found in the RME group. A significant difference was observed between the groups during this period. An anterior rotation tendency of the mandible and posterior tipping of the upper incisors could be responsible for this increase.

Conclusions

1. In relation to cranial base the maxilla moved forward in both groups; whereas the mandible showed a downward and backward rotation only in the RME group.
2. Increases in both the interincisal angle and the amount of overjet in both groups were observed.
3. Vertically and sagittally no significant difference was observed biometrically between the two groups.

Address for correspondence

Sevil Akkaya
Gazi Universitesi
Diş Hekimliği Fakültesi
Ortodonti Anabilim Dalı
06510/Emek-Ankara
Turkey

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