European Journal of Orthodontics 20 (1998) 255–261

Comparison of dental arch and arch perimeter changes 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 evaluate and compare the dental effects of bonded rapid maxillary expansion (RME) and bonded slow maxillary expansion (SME) treatment methods. Subjects with a maxillary bilateral crossbite were selected and two treatment groups each with 12 patients were constructed. At the beginning of treatment, the average chronological ages were 11.96 years for the RME group and 12.31 years for the SME group. 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. The treatment time for the RME group varied from 0.70 to 1.60 months and for the SME group 1.00–5.16 months. At the end of active treatment the appliances were worn for retentive purpose for an additional 3 months. Orthodontic casts taken at the beginning and end of treatment, and at the end of the retention period formed the material for the study. Increases in the transversal width between the upper molars, upper first premolars, upper canines, lower canines, and in the upper arch perimeter were obtained. The increase in the upper inter-canine width was found to be significantly greater in the RME group compared with the SME group. Regression analysis indicated that arch perimeter gain through the treatment could be predicted as 0.65 times the amount of the posterior expansion for the RME group and 0.60 times the amount of posterior expansion for the SME group.

Introduction

Aetiological causes of buccolingual discrepancies can be either genetic or environmental. Harvold *et al.* (1972) stated that upper arch narrowness was generally due to anomalous functions. Posterior crossbite is one of the most commonly seen transversal malocclusions generally accompanied with upper arch crowding (Harvold *et al.*, 1972; Bishara and Staley, 1987). The current trend in orthodontics has shifted towards the principles of dentofacial orthopaedics and non-extraction treatment modalities. Maxillary expansion appliances increase available arch length and result in the correction of posterior crossbite (Adkins *et al.*, 1990). However, Krebs (1964) demonstrated stable increases in the maxillary base and nasal cavity but diminution in width of the dental arch following mid-palatal separation.

Several authors have recommended different types of maxillary expansion appliances by changing the rate of expansion and form of the appliance. With maxillary expansion treatment, the aim is to achieve minimal dental and maximum skeletal effects (Haas, 1961). Rapid maxillary expansion appliances show the best examples of true orthopaedics in that changes are produced primarily in the underlying structures and therefore are found to be more stable (Haas, 1980; Bishara and Staley, 1987; Adkins *et al.*, 1990; McNamara, 1993). However, clinical and histological studies have shown that relapse, microtrauma of the temporomandibular joint, microfractures at the mid-palatal suture and especially external root resorption are observed in rapid maxillary expansion treatment (Linder-Aronson and Lindgren, 1979; Barber and Sims, 1981; Langford, 1982). To eliminate these disadvantages and obtain increased physiological tissue reaction, slow maxillary expansion has become more popular (Mew, 1983; Vardimon *et al.*, 1991). It has also been shown that slow maxillary expansion has orthopaedic effects (Cotton, 1978; Hicks, 1978; Bell and LeCompte, 1981; Mossaz-Joëlson and Mossaz, 1989).

Recently, the use of bonded expanders has been recommended as these result in less tooth tipping compared with banded expanders. In addition, the acrylic occlusal coverage opens the bite posteriorly, facilitating the correction of crossbites (Howe, 1982; Spolyar, 1984).

In several studies changes in maxillary and mandibular inter-canine, and inter-molar widths have been recorded through maxillary expansion (Haas, 1965, 1970; Timms, 1980). The opening of a diastema between the maxillary central incisors has also been reported by several authors (Haas, 1961, 1965; Wertz, 1970).

Though changes in the dental arch after maxillary expansion treatment have been reported, comparison of different force duration has not previously been investigated. The purpose of this study was to evaluate the effects of bonded rapid maxillary expansion (RME) and bonded slow maxillary expansion (SME) treatment on dental arch and arch perimeter, and to compare the obtained results.

Subjects and methods

The sample included 24 patients with maxillary bilateral crossbite caused by basal apical narrowness, and showing a Class I or II molar relationship. Following examination by an otolaryngologist, none of the patients showed a nasal obstruction requiring surgical intervention.

Two treatment groups (with 12 patients in each) were constructed. The first group was treated by bonded RME and the second group 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. At the beginning of treatment, the average skeletal ages were 12.10 years (10.41–13.66) for the RME group and 12.19 years (9.91–13.75) for the SME group.

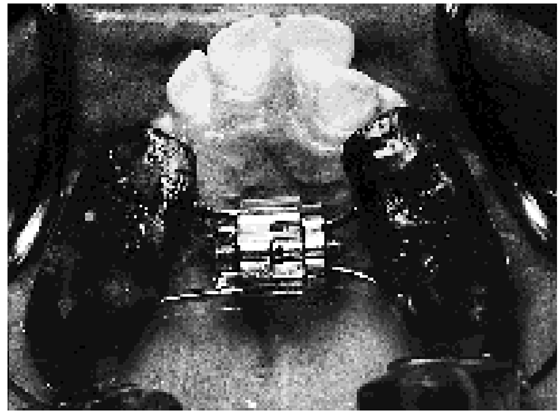

Figure 1 Occlusal view of a rapid maxillary expansion appliance.

Figure 2 Occlusal view of a slow maxillary expansion appliance.

A Hyrax appliance was used in the RME treatment group and a Minne Expander in the SME group (Figures 1 and 2). Both were embedded in the posterior bite plates, which had a thickness of 1 mm. The mid-point of the palatinal and buccal surfaces, and cusp tips of the upper premolars or deciduous molars and first molars were etched with a 37 per cent solution of phosphoric acid. After rinsing and drying the etched teeth, the maxillary expansion appliances were bonded with Paladur (Kulzer, Hereaus, Germany). The Hyrax screws were activated by the patients twice a day with a one-quarter turn in the morning and in the evening. The Minne Expanders were compressed each week to

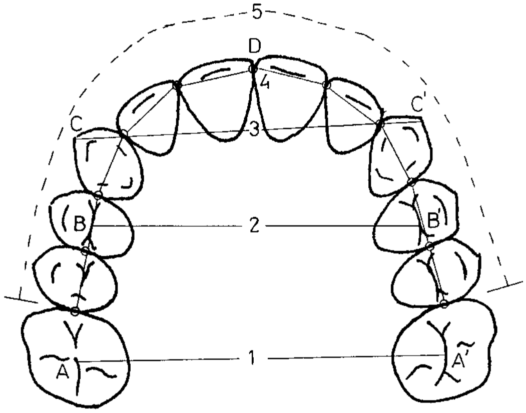

Figure 3 Dental points and measurements in the maxillary arch. 1, Intermolar width (6 + 6): the distance between the mid-point of the distobuccal and mesiopalatal cusps of the upper first molar (A–A′). 2, Interpremolar width (4 + 4): the distance between the mid-point of the central fossa of the upper deciduous first molar or first premolar (B–B′). 3, Intercanine width (3 + 3): the distance between the upper canine cusps (C–C′). 4, Interincisor width (1 + 1): the distance between the mesial aspect of the upper central incisors (D). 5, Arch perimeter was measured between the mesial aspect of the first molars, over the contact points of posterior teeth and incisal edge of the anteriors. If there was a diastema, mesiodistal width was added to this measurement.

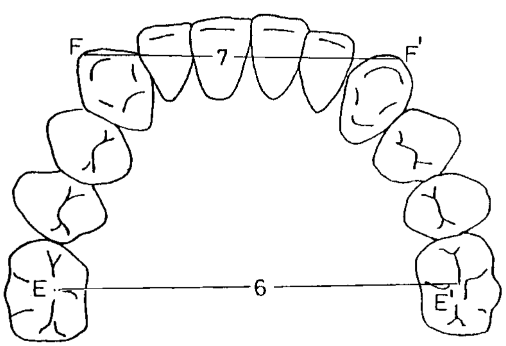

Figure 4 Dental points and measurements in the mandibular arch. 6, Intermolar width (6–6): the distance between the mid-point of the distobuccal and mesiopalatal cusps of the lower molars (E–E′). 7, Intercanine width (3–3): the distance between the lower canine cusps (F–F′).

produce a continuous force of 900 g. The subjects were observed weekly until over-correction was obtained, insofar as the palatal cusp of the upper molar was in a similar plane to the buccal cusp of

Table 1 Method error co-efficients.

	Parameter	*r*
Maxilla	1. 6 + 6	0.98
	2. 4 + 4	0.98
	3. 3 + 3	0.99
	4. 1 + 1	0.99
	5. Arch perimeter	0.97
Mandible	6. 6 – 6	0.99
	7. 3 – 3	0.94

lower molar. At that time both appliances were removed in order to facilitate impressions, then replaced and used as a retention device. The retention period continued for 3 months.

Maxillary and mandibular study casts were taken at the beginning and end of treatment, and at the end of the retention period. Points from which measurements were to be taken were marked with 0.3 mm pencil. All measurements were read to the nearest 0.1 mm (Figures 3 and 4).

For all casts all parameters were measured again after 15 days and measurement error was determined. All measurement error coefficients were found to be near 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 retention; at the beginning of treatment and at the end of retention were evaluated with the paired *t*-test. A Student's *t*-test was applied for comparison of the groups. To estimate the arch perimeter changes, a regression analysis was performed between the arch perimeter and inter-molar, inter-premolar, and inter-canine widths.

Results

Table 2 shows the means, standard deviations and the significance of the treatment, post-treatment and net changes for RME group. The increase during treatment was significant for all parameters in this group. In the post-treatment interval there was a significant decrease in inter-canine, inter-incisor width, and arch perimeter in the maxillary arch. Inter-molar and inter-canine

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

		Pretreatment (1)		Post-treatment (2)		Post-retention (3)		*P*		
	Parameter	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	1–′2	2–′3	1–′3
Maxilla	1. 6 + 6	42.82	0.79	51.87	0.59	51.65	0.74	***		***
	2. 4 + 4	31.75	0.58	41.29	0.66	41.06	0.69	***		***
	3. 3 + 3	29.38	0.90	35.73	0.81	34.71	0.76	***	***	***
	4. 1 + 1	0.39	0.28	4.07	0.62	0.53	0.34	***	***	
	5. Arch perimeter	67.53	1.17	74.38	1.27	72.59	1.11	***	***	***
Mandible	6. 6 – 6	44.78	0.79	45.15	0.80	45.45	0.85	***	*	***
	7. 3 – 3	26.52	0.55	27.16	0.52	27.56	0.54	***	*	***

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

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

		Pretreatment (1)		Post-treatment (2)		Post-retention (3)		*P*		
	Parameter	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	1–′2	2–′3	1–′3
Maxilla	1. 6 + 6	43.69	0.96	53.50	0.63	53.30	0.65	***		***
	2. 4 + 4	31.45	0.90	41.30	0.80	41.00	0.78	***		***
	3. 3 + 3	31.12	0.77	35.27	0.78	34.50	0.73	***	**	***
	4. 1 + 1	0.00	–	0.00	–	0.00	–			
	5. Arch perimeter	68.14	1.12	74.05	0.86	73.00	0.89	***	***	***
Mandible	6. 6 – 6	44.64	0.93	45.08	0.89	45.33	0.88	*	***	***
	7. 3 – 3	26.55	0.39	27.35	0.38	27.65	0.39	***	*	***

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

width in the mandibular arch showed a statistically significant increase post-treatment in the RME group (Table 2).

Table 3 shows the means, standard deviations, and the significance of the treatment, post-treatment, and net changes for the SME group. Except inter-incisor width, all parameters were significantly increased during treatment in this group. In the post-treatment interval a significant decrease was observed in inter-canine width and arch perimeter in the maxillary arch. Inter-molar and inter-canine widths in the mandibular arch also showed a significant increase post-treatment (Table 3).

For both groups the net change was significant for all parameters except inter-incisor width (Tables 2 and 3).

Comparison between the RME and SME groups

Increases in inter-canine and inter-incisor widths were significantly greater in the RME than SME group during treatment. In the post-treatment interval the decrease in inter-incisor width and arch perimeter in RME group showed a significant difference compared with the SME group. The net change for inter-canine width exhibited a statistically significant difference between the groups (Table 4).

Linear regresion analysis of the three independent variables (inter-molar, inter-premolar, and inter-canine width increase in the maxillary arch) showed that premolar width increase was the best predictor of the increase in arch perimeter for both the treatment and post-treatment

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

		Treatment change					Post-treatment change					Net change				
		RME group		SME group			RME group		SME group			RME group		SME group		
	Parameter	$\bar{D}$	$S\bar{D}$	$\bar{D}$	$S\bar{D}$	*P*	$\bar{D}$	$S\bar{D}$	$\bar{D}$	$S\bar{D}$	*P*	$\bar{D}$	$S\bar{D}$	$\bar{D}$	$S\bar{D}$	*P*
Maxilla	1. 6 + 6	9.05	0.40	9.81	0.57		–0.22	0.19	–0.20	0.06		8.83	0.32	9.60	0.53	
	2. 4 + 4	9.54	0.49	9.85	0.57		–0.22	0.25	–0.30	0.09		9.31	0.43	9.55	0.57	
	3. 3 + 3	6.35	0.45	4.15	0.49	**	–1.01	0.15	–0.77	0.18		5.33	0.49	3.37	0.44	**
	4. 1 + 1	3.68	0.56	0.00	–	***	–3.54	0.55	0.00	–	***	0.14	0.09	0.00	–	
	5. Arch perimeter	6.85	0.38	5.90	0.49		–1.79	0.32	–1.04	0.15	*	5.05	0.39	4.86	0.43	
Mandible	6. 6 – 6	0.36	0.07	0.44	0.14		0.30	0.10	0.25	0.05		0.67	0.14	0.69	0.14	
	7. 3 – 3	0.64	0.07	0.80	0.14		0.40	0.14	0.29	0.12		1.04	0.12	1.09	0.20	

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

periods. This relationship was represented by the following equations: for the RME group, Arch perimeter change = 0.62 + 0.65 × premolar width change (*R*–Sq(adj) = 67.5 per cent); the SME group, Arch perimeter change = 0.03 + 0.60 × premolar width change (*R*–Sq(adj) = 43.4 per cent).

For the pretreatment – post-retention (net change) interval the following equations were represented.

RME group: Arch perimeter change = 0.01 + 0.54 × premolar width change (*R*–Sq(adj) = 30.6 per cent).

SME: Arch perimeter change = 0.16 + 0.52 × premolar width change (*R*–Sq(adj) = 42.4 per cent).

Discussion

Application of expansion is generally to avoid the extraction of permanent teeth and thus determination of dental changes through RME and SME treatment would be helpful in planning orthodontic treatment.

During the treatment period inter-molar width showed an increase of 9.05 mm in the RME group and 9.81 mm increase in the SME group. This change occurred as a result of opening of the mid-palatal suture, bending and moving of the alveolar processes laterally, and buccal tipping of the anchorage teeth (Haas, 1961; Barber and Sims, 1981; Langford, 1982; Langford and Sims, 1982). Both in studies of RME and SME a significant increase in inter-molar width has been reported (Haas, 1961, 1970; Cotton, 1978; Hicks, 1978; Timms, 1980; Bell and LeCompte, 1981; Mossaz-Joëlson and Mossaz, 1989).

In all groups inter-premolar width change was approximately the same as the inter-molar width change. This is in agreement with the findings of a RME study (Wertz, 1970). In an experimental SME study it was reported that inter-premolar width increased 7.5–9 mm while inter-molar width showed a 6.9–9.6 mm increase (Cotton, 1978).

Mossaz-Joëlson and Mossaz (1989) noted that inter-canine width showed a smaller increase than inter-molar width in the maxillary arch, both in bonded and banded Minne Expander groups. This is in agreement with our findings for RME and SME groups. Contrary to these findings, it has been reported that opening of the mid-palatal suture is greater in the anterior than posterior region (Wertz, 1970; Biederman, 1973; Ekström *et al.*, 1977; Bell and Le-Compte, 1981). As the appliances used in this study were not anchored to canine teeth, this result is not a surprise. However, the increase in upper intercanine width in the RME group was greater than in the SME group. The longer treatment time in the SME group permits the perioral muscles to be more effective on upper canines. In the post-treatment interval the upper inter-canine width was decreased 1.01 mm in the RME group and 0.77 mm in the SME group. Herold (1989) after a 5-month retention period observed a 0.8 mm decrease in the SME group and 1.3 mm decrease in RME group for upper canine width. Haas (1980) reported that after a few years without retention upper canine width remained the same. Some authors, however, have reported a greater relapse in inter-canine width than in inter-molar width in the maxillary arch (Krebs, 1964; Linder-Aronson and Lindgren, 1979).

The opening of a diastema between the maxillary central incisors is one of the changes accompanying RME. Later, the incisor crowns show a mesial tipping caused by the elastic recoil of the transeptal fibres (Haas, 1961, 1965, 1970; Wertz, 1970). While the inter-incisor width was increased in the RME group, no difference was observed in the SME group at the end of treatment. Opening of a diastema has also not been reported in other SME studies (Ekström *et al.*, 1977; Mossaz-Joëlson and Mossaz, 1989). As the treatment time was longer in this group transeptal fibres caused the tipping of the crowns before the end of the active treatment. In the RME group, a significant decrease was observed at the end of the retention period.

While the diastema between the upper incisors was closed, arch perimeter was increased and space was gained for rotation or impacted teeth (Haas, 1961, 1980; Bishara and Staley, 1987; McNamara, 1993). At the end of treatment the arch perimeter increase in the RME and SME groups was 6.85 and 5.90 mm, respectively. This was not statistically significant.

Adkins *et al.* (1990) reported that RME with the Hyrax appliance produced increases in maxillary arch perimeter at the rate of approximately 0.7 times the change in premolar width. In this study, by regression analysis, inter-premolar width was determined as the best predictor of the increase in arch perimeter. Evaluation of the prediction equations show that increase in arch perimeter through treatment was 0.65 times the amount of the posterior expansion for the RME group and 0.60 times the amount of expansion for the SME group. Though there was some decrease in the retention period, the net increase gain in arch perimeter was 5.05 mm for the RME group and 4.86 mm for the SME group. The prediction equations for the net change indicated that perimeter gain for the RME group could be predicted as 0.54 times the amount of expansion in premolar width and for the SME group 0.52 times the amount of expansion. As there was a decrease in arch perimeter in the retention period, the use of fixed retainers would be necessary especially for borderline cases.

The increase in inter-canine and inter-molar width in the mandibular arch during treatment was related to the altered muscular balance exerted on the dentition and the altered forces of occlusion. This increase might also be attributed to the lowered position of the tongue due to the palatal position of the appliances (Haas, 1961, 1980; Cotton, 1978; Adkins *et al.*, 1990; Halazonetis *et al.*, 1994). A significant increase was also observed in lower inter-canine and inter-molar widths at the end of the retention period. This significant increase was expected as the posterior bite plates eliminated the effect of relapse of the upper inter-molar width in the lower arch.

Conclusions

1. Increase in upper inter-canine width was significantly greater in the RME group than in the SME group. This could be related to the faster increase in width in the RME group.
2. Regression analysis indicated that arch perimeter gain through treatment could be predicted as 0.65 times the amount of the posterior expansion for the RME group and 0.60 times the amount of posterior expansion for the SME group.
3. Evaluation of the prediction equations showed that RME produces increases in the maxillary arch perimeter at the rate of 0.54 times the change in first premolar width at the end of the retention period. For the SME group arch perimeter gain could be predicted as 0.52 times the amount of posterior expansion at the end of the retention period.

Address for correspondence

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

References

Adkins M D, Nanda R S, Currier G F 1990 Arch perimeter changes on rapid palatal expansion. American Journal of Orthodontics and Dentofacial Orthopedics 97: 194–199

Barber A F, Sims M R 1981 Rapid maxillary expansion and external root resorption in man: a scanning electron microscope study. American Journal of Orthodontics 79: 630–652

Bell R A, LeCompte E J 1981 The effects of maxillary expansion using a quad-helix appliance during the deciduous and mixed dentitions. American Journal of Orthodontics 79: 152–161

Biederman W 1973 Rapid correction of Class III malocclusion by mid-palatal expansion. American Journal of Orthodontics 63: 47–55

Bishara S E, Staley R N 1987 Maxillary expansion: clinical implications. American Journal of Orthodontics and Dentofacial Orthopedics 91: 3–14

Cotton L A 1978 Slow maxillary expansion: skeletal versus dental response to low magnitude force in *Macaca mulatta*. American Journal of Orthodontics 73: 1–23

Ekström C, Henrikson C O, Jensen R. 1977 Mineralization in the mid-palatal suture after orthodontic expansion. American Journal of Orthodontics 71: 449–455

Haas A J 1961 Rapid expansion of the maxillary dental arch and nasal cavity by opening the mid-palatal suture. Angle Orthodontist 31: 73–90

Haas A J 1965 The treatment of maxillary deficiency by opening the mid-palatal suture. Angle Orthodontist 35: 200–217

Haas A J 1970 Palatal expansion: just the beginning of dentofacial orthopaedics. American Journal of Orthodontics 57: 219–255

Haas A J 1980 Long-term post-treatment evaluation of rapid palatal expansion. Angle Orthodontist 50: 189–217

Halazonetis D J, Katsavrias E, Spyropoulos M N 1994 Changes in cheek pressure following rapid maxillary expansion. European Journal of Orthodontics 16: 295–300

Harvold E P, Chierici G, Vargervik K 1972 Experiments on the development of dental malocclusions. American Journal of Orthodontics 61: 38–44

Herold J 1989 Maxillary expansion: a retrospective study of three methods of expansion and their long-term sequelae. British Journal of Orthodontics 16: 195–200

Hicks E P 1978 Slow maxillary expansion: a clinical study of the skeletal versus dental response to low-magnitude force. American Journal of Orthodontics 73: 121–141

Howe R P 1982 Palatal expansion using a bonded appliance. American Journal of Orthodontics 82: 464–468

Krebs Å 1964 Midpalatal suture expansion studied by the implant method over a seven-year period. Transactions of the European Orthodontic Society, pp. 131–142

Langford S R 1982 Root resorption extremes resulting from clinical RME. American Journal of Orthodontics 81: 371–377

Langford S R, Sims M R 1982 Root surface resorption, repair, and periodontal attachment following rapid maxillary expansion in man. American Journal of Orthodontics 81: 108–115

Linder-Aronson S, Lindgren J 1979 The skeletal and dental effects of rapid maxillary expansion. British Journal of Orthodontics 6: 25–29

McNamara J A 1993 Orthodontic and orthopaedic treatment in mixed dentition. Needham Press Inc., Ann Arbor

Mew J R C 1983 Relapse following maxillary expansion. A study of twenty five consecutive cases. American Journal of Orthodontics 83: 56–61

Mossaz-Joëlson K, Mossaz C F 1989 Slow maxillary expansion: a comparison between banded and bonded appliances. European Journal of Orthodontics 11: 67–76

Spolyar J L 1984 The design, fabrication, and use of a full-coverage bonded rapid maxillary expansion appliance. American Journal of Orthodontics 86: 136–145

Timms D J 1980 A study of basal movement with rapid maxillary expansion. American Journal of Orthodontics 77: 500–507

Vardimon A D, Graber T M, Voss L R, Lenke J 1991 Determinants controlling iatrogenic external root resorption and repair during and after palatal expansion. Angle Orthodontist 61: 113–122

Wertz R A 1970 Skeletal and dental changes accompanying rapid mid-palatal suture opening. American Journal of Orthodontics 58: 41–66