An evaluation of the dentoskeletal effects of slow maxillary expansion from the mixed to the permanent dentition

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Introduction: The aim of this study was to evaluate the dentoskeletal effects of a modified slow maxillary expansion appliance (MSMEA) during the transition from the mixed to the permanent dentition.
Methods: Forty subjects presenting with posterior crossbites were divided into two groups. Twenty-three subjects were assigned to a treatment group (mean age: 9.45 years) and 17 subjects assigned to a control group (mean age: 9.25 years). An MSMEA with acrylic occlusal coverage limited to the palatal cusps was used to provide maxillary expansion. The mean slow expansion treatment period was 7.8 months, while the mean observation period continued for 14.8 months of a 22.6-month total study period.
Results: Substantial dental and skeletal effects were observed following treatment with the MSMEA. Most maxillary inter-molar and deciduous inter-second molar width increases were maintained in the permanent dentition (91% and 97%, respectively). Skeletal maxillary transverse dimensions, which increased by 2 mm after active expansion, were significantly greater ($p < 0.001$) when compared with the controls.
Conclusion: The findings suggested that an MSMEA provided orthopaedic and dental effects as a result of posterior crossbite correction. The effects of the appliance seen during the mixed dentition were maintained in the permanent dentition.
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Introduction

A posterior crossbite is a commonly presenting feature of a developing dentition.[1] The prevalence of the problem in the mixed dentition is estimated to be between 2.7% and 12%.[2-4] Posterior crossbites are believed to be transferred from the primary to the permanent dentition, which may have long-term effects on dentofacial growth and development.[5,6] Therefore, it is important to recognise the early development of an arch-width discrepancy and to implement the appropriate management procedures.

There are different views regarding the timing and type of treatment required for posterior crossbite management. Early intervention has generally been recommended since spontaneous correction is not common.[3,7,8] It is considered that early correction favourably influences the eruptive paths of the permanent teeth and allows normal development of the alveolar processes and temporomandibular joints.[9] However, early expansive treatment is controversial with respect to its cost-to-benefit ratio.[10] In addition, there is no clear consensus regarding the stability of slow maxillary expansion (SME) in the late mixed dentition stage. In a comparison of four expansion groups, Bartzela and Jonas found that a midline correction was significantly greater in the late (mixed dentition) SME group.[10] Furthermore, Sari et al. compared the effects of rapid maxillary expansion (RME) applied in the late mixed dentition or early permanent dentition[11] and suggested that RME should be delayed until the early permanent dentition.

It was reported that tipping of the maxillary molars was greater and orthopaedic effects of the RME were less that expected compared with earlier treatment.

A range of treatment options are available for the management of posterior crossbites.[12] In a systematic review, Petrén et al. emphasised that appliances such as the Quad-helix (QH), expansion plates, and RME were effective and successful when applied in the early mixed dentition.[5] Slower rates of expansion that allowed for a more physiologic adaptation of sutures during expansion have been advocated.[13,14] However, since most appliances are tooth-borne or tooth-tissue-borne, the exfoliation of primary teeth may occur during active expansion and, consequently, the applied force may not be transmitted to the alveolar base. Although longitudinal effects of an RME have been investigated,[15-18] there are few studies that have been directed at the longitudinal effects of SME during the transitional dentition.[1,13,19]

Therefore, the objectives of the present study were to (1) evaluate the dentoskeletal effects of a modified slow maxillary expansion appliance (MSMEA) in the late mixed dentition, (2) determine the extent of relapse, and (3) compare the observed effects with an untreated control group.

Materials and methods

Approval was obtained from the Ethics Committee of the Suleyman Demirel University Medical Faculty and informed consent was provided by all patients prior to the commencement of the study. The following inclusion criteria were applied in selecting the study groups: (1) unilateral or bilateral posterior crossbite, (2) in the mixed dentition, (3) no previous orthodontic treatment, (4) the presence of maxillary first and second deciduous molars, (5) good oral hygiene, (6) the absence of severe sagittal or vertical skeletal anomalies, and (7) no congenitally missing teeth. Initially, 50 patients were included and were equally divided into two groups comprising a treatment and control group (25 patients in each group). Patients who exhibited maxillary first deciduous molar mobility were assigned to the control group due to the likelihood of these teeth exfoliating during the active expansion treatment. However, eight patients from the control group were excluded from the study for failing to regularly attend prearranged follow-up appointments, and two patients from the expansion group were excluded because of poor compliance. Consequently, 40 patients, comprised of 23 from the treatment group and 17 patients from the control group, were subjected to the final analysis. At the start of treatment, the mean patient age was 9.24 years and 9.40 years in the treatment and control groups, respectively (Table I).

A removable appliance with an expansion screw was inserted in all patients in the treatment group. The plate was constructed to cover the occlusal surfaces of the posterior teeth and therefore eliminate interferences during expansion and provide vertical control. However, the occlusal coverage was removed on the vestibular surface of the buccal cusps of the posterior teeth to minimise the possibility of molar tipping (Figure 1). This novel design prevented the extrusion of the palatal cusps by means of the occlusal acrylic coverage. The appliance was worn full-time and the parents were instructed to activate the appliance screw once every four days at bedtime. The expansion procedures continued until a 2 mm overcorrection was obtained. Thereafter, the same appliance was used as a retainer up to the time of eruption of the premolars and the canine cusps into the oral cavity. The course of treatment is illustrated in Figures 2–4. The control group was observed over the same period and deciduous canine reduction was performed in some patients to eliminate functional shifts.

The examinations were conducted at three time intervals: at the initial assessment (T_0), after the expansion protocol in the expansion group and control period in the control group (T_1), and the early permanent dentition (T_2). Lateral and frontal

Figure 1. Modified slow maxillary expansion appliance (MSMEA).

Table I. Comparison of pretreatment dental cast and frontal and lateral radiographic parameter values between the expansion and control groups.

		Expansion group N = 23	Control group N = 17	
		X±Sx	X±Sx	*p*
Chronologic age (year)	T_0	9,45±0,20	9,28±0,21	NS
	T_1	10,11±0,20	10,18±0,17	NS
	T_2	11,33±0,20	11,08±0,19	NS
Dental measurements				
Maxillary III–III width		28,99±0,35	29,75±0,71	NS
Maxillary IV–IV width		35,67±0,37	37,31±0,70	*
Maxillary V–V width		39,99±0,40	41,16±0,72	NS
Maxillary 6–6 width		47,12±0,51	47,76±0,77	NS
Mandibular III–III width		25,53±0,41	26,16±0,43	NS
Mandibular 6–6 width		45,68±0,57	46,27±0,66	NS
Maxillary arch depth		28,71±0,59	29,56±0,52	NS
Mandibular arch depth		25,90±0,37	26,13±0,42	NS
Frontal cephalometric measurements				
Inter-nasal width		29,74±0,34	30,34±0,50	NS
Inter-maxillary width		63,70±0,55	63,83±0,67	NS
Inter-gonial width		84,10±1,19	83,78±1,05	NS
Maxillary inter-molar apical width		41,40±0,84	41,99±0,92	NS
Maxillary inter-molar width		56,40±0,59	56,48±0,74	NS
Mandibular inter-molar width		59,46±0,50	59,30±0,64	NS
Maxillary right molar axis		109,48±1,00	108,88±1,13	NS
Maxillary left molar axis		109,30±1,02	107,91±1,36	NS
Lateral cephalometric measurements				
SNA°		76,02±0,62	79,07±0,86	**
SNB°		74,90±0,67	76,56±0,79	NS
ANB°		1,13±0,48	2,52±0,60	NS
SN/PP°		9,18±0,75	9,36±0,86	NS
SN/MP°		40,12±1,22	37,42±1,21	NS
PP/MP°		30,94±1,23	28,06±1,29	NS
Skeletal linear measurements				
N-Me (mm)		114,47±1,24	113,45±1,30	NS
N-ANS (mm)		51,12±0,73	50,77±0,65	NS
ANS-Me (mm)		65,00±1,14	64,42±1,08	NS
ANS-Me/N-Me		0,57±0,01	0,57±0,01	NS
ANS-PNS (mm)		50,47±0,68	50,97±0,63	NS
Co-A (mm)		80,36±0,98	81,78±0,88	NS
Co-Go (mm)		52,38±0,85	52,61±0,92	NS
Dentoalveolar measurements				
U1/PP°		72,81±1,66	68,68±1,36	NS
L1/MP°		86,90±1,37	90,38±1,72	NS
U1/L1°		134,97±2,06	130,24±2,51	NS
U1-NA (mm)		2,51±0,48	3,25±0,45	NS
L1-NB (mm)		3,08±0,40	4,02±0,60	NS
Overjet (mm)		0,65±0,44	2,15±0,46	*
Overbite (mm)		1,30±0,58	1,76±0,35	NS

NS: Non significant, * $p < 0.05$, ** $p < 0.01$

Figure 2. Pretreatment intra-oral and extra-oral photographs of a patient.

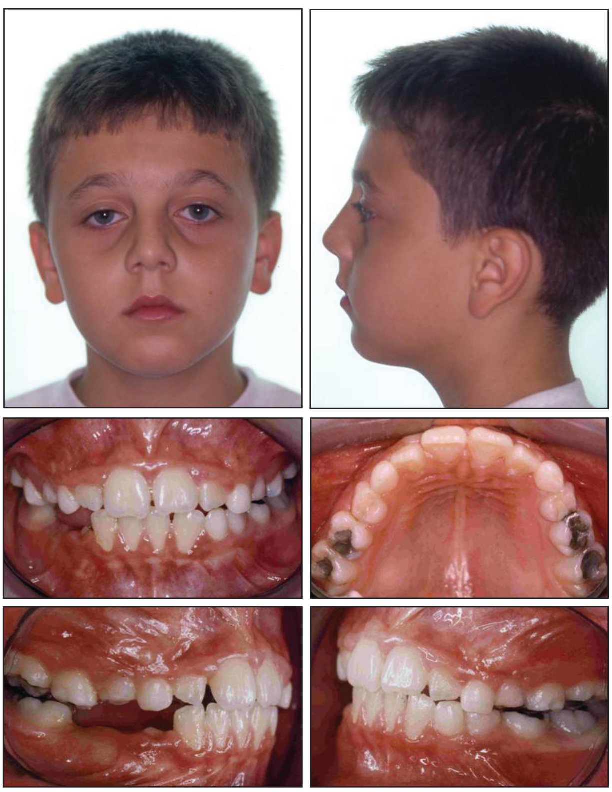

Figure 3. Intra-oral and extra-oral photographs of a patient after expansion procedure.

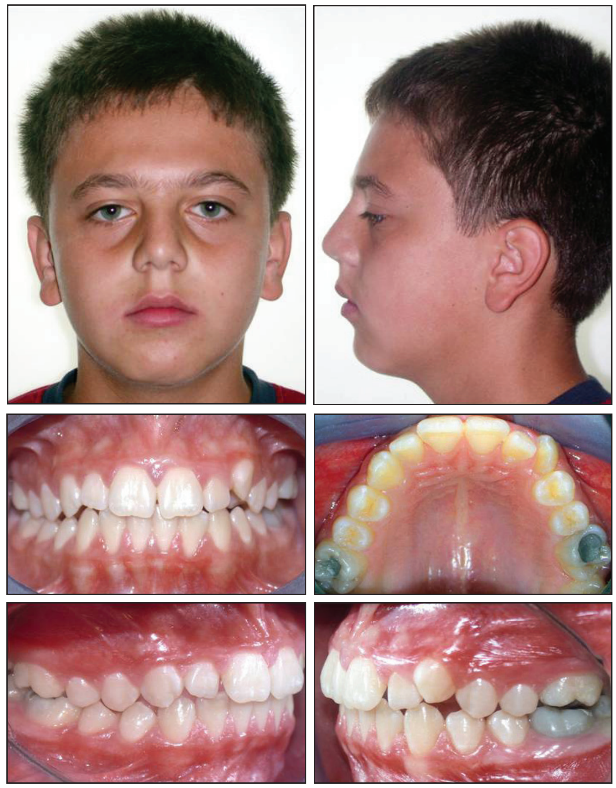

Figure 4. Intra-oral and extra-oral photographs of a patient after retention period.

cephalometric radiographs, dental casts, and intra-oral and extra-oral photographs were obtained at these time intervals. Standardised occlusal radiographs were taken at the pre- and post-expansion periods in the treatment group, and the appearance of a radiolucent line in the mid-palatal suture area was considered as evidence of mid-palatal suture opening. The parameters used in this study are listed below.

Dental cast parameters

The maxillary and mandibular inter-molar (6-6), inter-canine (III–III/3–3), and maxillary inter-premolar (IV–IV/4–4 and V–V/5–5) arch widths were recorded. The distances between the mesiobuccal cusp tips were used for measuring posterior arch widths by means of a digital caliper. The maxillary and mandibular arch depths were also measured (Figure 5).

Frontal cephalometric measurements

Inter-nasal, inter-maxillary base (the distance between the right and left jugal processes), inter-gonial, and maxillary inter-molar widths, maxillary right and left molar axes, and inter-molar apical widths were

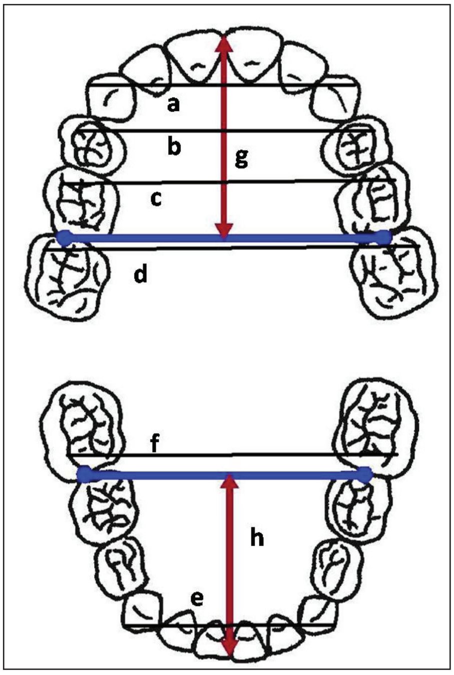

Figure 5. Dental cast measurements: (a) maxillary intercanine width, (b-c) maxillary inter-premolar widths, (d) maxillary inter-molar width, (e) mandibular inter-canine width, (f) mandibular inter-molar width, (g) maxillary arch depth, (h) mandibular arch depth.

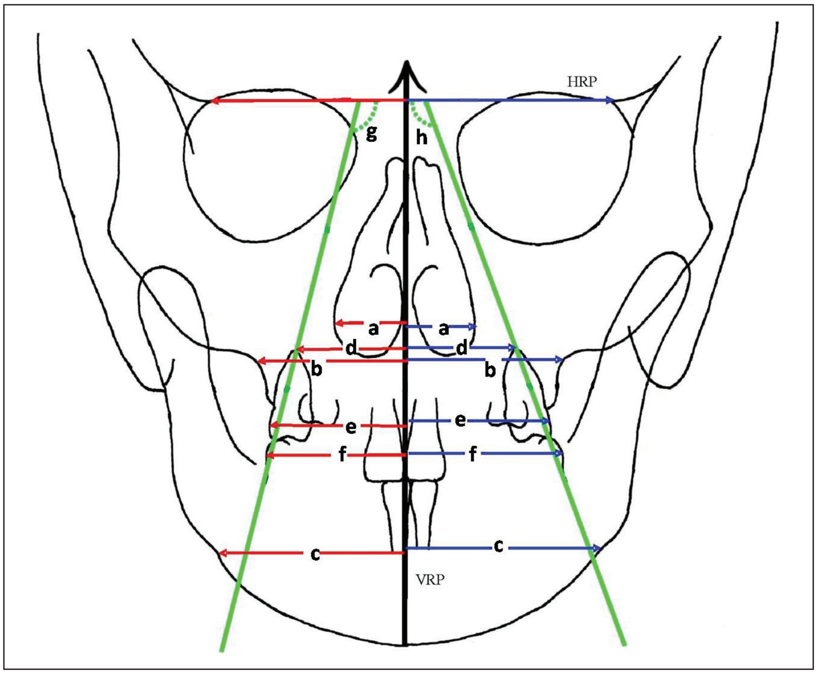

Figure 6. Frontal cephalometric measurements. HRP: Horizontal reference plane (between right and left latero-orbitale points). VRP: Vertical reference plane (perpendicular to HRP). (a) inter-nasal width, (b) inter-maxillary width, (c) inter-gonial width, (d) maxillary inter-molar apical width, (e) maxillary inter-molar width, (f) mandibular inter-molar width, (g-h) maxillary right and left molar axes.

measured. Maxillary molar axis was measured as the angle between the long axis of the maxillary first molar and the horizontal plane. The long axis was traced between the buccal apices of its root (Figure 6).

Lateral cephalometric measurements

Radiographs were hand-traced with a 0.5 mm pencil and the parameters measured to the nearest 0.5 mm and 0.5°. SNA, SNB, ANB, SN-GoGn, SN-PP and PP-MP angles, maxillary and mandibular effective lengths, palatal length (ANS-PNS), anterior facial height, and the ratio of the anterior lower height to total height (N-Me, N-ANS, ANS-Me) were measured. Overjet and overbite were also recorded.

Statistical analyses

Data analysis was performed using SPSS for Windows, version 11.0 (IBM Corporation, NY, USA). One-third of the patients' dental and cephalometric parameters were remeasured after one month and the first and second measurements were compared using a paired *t*-test. No statistical difference was found between the two measurements. The correlation coefficient (r) was found to range between 0.923 and 0.999 for all parameters.

Parametric tests were applied and the normality of continuous variables was determined using the Shapiro-Wilk test. The Student's *t*-test was applied to compare values obtained in the pretreatment, post-expansion, and post-retention intervals. Changes between the observation intervals for intragroup comparisons were assessed by the paired *t*-test. A p value of less than 0.05 was considered statistically significant.

Results

Of the dental and skeletal parameters analysed at the start of treatment, most were found to be similar between the groups, except for the maxillary first deciduous inter-molar width and the SNA angle (Table I).

Dental cast measurements

Maxillary expansion using an MSMEA resulted in a statistically significant increase in the inter-canine, inter-premolar, and inter-molar widths ($p < 0.001$)

Table II. The changes in values of dental cast and frontal radiographic measurements during different periods.

	Expansion group N = 23			Control group N = 17		
	T_1-T_0	T_2-T_1	T_2-T_0	T_1-T_0	T_2-T_1	T_2-T_0
Dental measurements	X±Sx	X±Sx	X±Sx	X±Sx	X±Sx	X±Sx
Maxillary III–III (3–3) width	5,52±0,34***	-0,81±0,41	4,70±0,40***	0,79±0,36 *	0,95±0,32 **	1,74±0,50 **
Maxillary IV–IV (4–4) width	6,13±0,33***	-0,66±0,40	5,48±0,48***	0,49±0,36	0,86±0,27 **	1,35±0,38 **
Maxillary V–V (5–5) width	7,27±0,30***	-0,15±0,41	7,11±0,46***	0,78±0,36 *	0,79±0,46	1,57±0,62 *
Maxillary 6–6 width	7,72±0,30***	-0,68±0,18***	7,04±0,33***	0,35±0,15 *	0,26±0,10 *	0,61±0,20 **
Mandibular III–III (3–3) width	0,75±0,33*	0,08±0,29	0,83±0,40*	-0,05±0,17	-0,28±0,12 *	-0,33±0,27
Mandibular 6–6 width	0,89±0,24***	-0,33±0,17	0,56±0,33	0,04±0,18	-0,32±0,21	-0,28±0,30
Maxillary arch depth	-0,99±0,24***	1,33±0,43**	0,34±0,51	0,09±0,13	-0,50±0,14 **	-0,40±0,19
Mandibular arch depth	-0,37±0,12**	0,48±0,21*	-0,85±0,22***	-0,47±0,15 **	-0,50±0,15 **	-0,97±0,21***
Frontal cephalometric measurements						
Inter-nasal width	0,67±0,15 ***	0,27±0,18	0,94± 0,20 ***	0,18±0,21	0,91±0,17 ***	1,09±0,19 ***
Inter-maxillary width	2,07±0,19 ***	1,10±0,21 ***	3,17±0,27 ***	0,49±0,29	0,53±0,20 *	1,02±0,26 ***
Inter-gonial width	1,54± 0,25 ***	2,04±0,32 ***	3,59±0,42 ***	1,02±0,22 ***	1,33±0,17 ***	2,35±0,26 ***
Maxillary inter-molar apical width	2,33±0,37 ***	1,11±0,37 **	3,45±0,48 ***	-0,20±0,27	0,32±0,34	0,12±0,36
Maxillary inter-molar width	6,22±0,29 ***	0,12±0,33	6,34±0,40 ***	0,13±0,15	0,33±0,21	0,46±0,22
Mandibular inter-molar width	1,05±0,23 ***	0,15±0,22	1,20±0,25 ***	0,22±0,23	-0,35±0,29	-0,13±0,29
Maxillary right molar axis	7,51±0,91 ***	1,95±0,94	5,56±0,92 ***	1,33±0,54 *	0,07±0,72	1,41±0,81
Maxillary left molar axis	7,55±1,05 ***	-2,42±0,74 **	5,14±0,84 ***	0,37±0,72	-0,40±0,69	-0,03±0,76

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(Tables II and III). An average maxillary inter-molar width increase of 7.72 mm was found to be significant (T_1). This expansion decreased by 0.68 mm during the retention period, resulting in a net gain of 7 mm. A similar increase was observed in the maxillary V–V (5–5) width. Maxillary III–III (3–3) and maxillary IV–IV (4–4) widths exhibited 5.5 mm and 6 mm increases, respectively, after expansion. At the end of the retention period, 4.7 mm and 5.5 mm increases in widths remained. Seventy-eight to 98% of the expansion was maintained at the time of eruption of the maxillary premolars.

No significant changes in the mandibular inter-molar widths were observed during treatment. In addition, no significant differences were found in the increase of maxillary inter-molar width values when the measurements obtained by dental casts and frontal cephalometric radiographs were compared.

Mandibular arch depth decreased approximately 1 mm, while no significant changes were detected in maxillary arch depth at the end of the retention period.

Frontal cephalometric measurements

Inter-nasal width showed a 0.65 mm increase after expansion treatment and an approximately 1 mm increase during the total study period ($p < 0.001$; Table II). The control group showed a similar increase owing to normal growth. Inter-maxillary basal width also significantly increased, by 2 mm in the expansion group ($p < 0.001$). Further, there was a 1.1 mm increase during the retention period. However, the maxillary base width increased by 1 mm over the entire observation period in the control group and this difference was found to be statistically significant ($p < 0.001$; Table III). While the angulations of the maxillary molar teeth increased by 7.5° and 7.2° on the right and left sides, respectively, the increase in the maxillary inter-molar apical distance was 2.33 mm after expansion, with a further increase of 1.1

Table III. Mean differences in dental and frontal cephalometric measurements during different periods.

	Expansion-Control					
	T_1-T_0		T_2-T_1		T_2-T_0	
Dental measurements	X±Sx	*p*	X±Sx	*p*	X±Sx	*p*
Maxillary III–III (3–3) width	4,73±0,50	***	-1,76±0,55	**	2,97±0,63	***
Maxillary IV–IV (4–4) width	5,64±0,49	***	-1,51±0,52	**	4,13±0,65	***
Maxillary V–V (5–5) width	6,49±0,47	***	-0,95±0,62	NS	5,54±0,75	***
Maxillary 6–6 width	7,37±0,37	***	-0,94±0,23	***	6,43±0,42	***
Mandibulary III–III (3–3) width	0,80±0,41	NS	0,36±0,35	NS	1,16±0,52	*
Mandibulary 6–6 width	0,84±0,32	*	-0,01±0,27	NS	0,84±0,46	NS
Maxillary arch depth	-1,08±0,31	***	1,82±0,51	***	0,74±0,62	NS
Mandibulary arch depth	0,10±0,19	NS	0,01±0,28	NS	0,11±0,32	NS
Frontal cephalometric measurements						
Inter-nasal width	0,49±0,25	NS	-0,64±0,25	*	-0,15±0,29	NS
Inter-maxillary width	1,58±0,34	***	0,57±0,30	NS	2,15±0,38	***
Inter-gonial width	0,52±0,34	NS	0,72±0,40	NS	1,24±0,54	*
Maxillary inter-molar apical width	2,53±0,49	***	0,80±0,52	NS	3,33±0,64	***
Maxillary inter-molar width	6,09±0,37	***	-0,21±0,43	NS	5,88±0,50	***
Mandibular inter-molar width	0,84±0,33	*	0,51±0,35	NS	1,34±0,38	***
Maxillary right molar axis	6,17±1,16	***	-2,02±1,26	NS	4,15±1,28	**
Maxillary left molar axis	7,18±1,37	***	-2,01±1,04	NS	5,17±1,18	***

NS: Non significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

mm during the retention period. The right and left maxillary molars exhibited 5.5° and 5° of buccal tipping, respectively, at the end of the retention period, without any significant relapse of the maxillary inter-molar width. The above measurements did not show significant changes in the control group.

Lateral cephalometric measurements

The SNA angle was stable during the entire observation period in the expansion group, while it increased by 0.77° in the control group. This difference was found to be statistically significant ($p < 0.01$; Table IV). The SNB angle increased slightly in both groups (0.75° and 0.54° in the expansion and control groups, respectively) and these changes were similar between the groups. The SN/MP angle increased slightly after expansion (1.23°) and decreased (1.43°) during the retention period and so no statistically significant difference was observed. Similarly, other vertical plane angles (SN/PP and PP/MP) showed no change during the entire study period. However, SN/MP and PP/MP showed a slight increase (1 mm) in the control group, but there were no statistically significant differences between the groups (Table V).

Significant increases in maxillary incisor protrusion and inclination were observed in the expansion group compared with those of the control group ($p < 0.01$; Table V). Mandibular incisor position and overjet remained steady in both groups. Overbite did not change after the expansion, but showed approximately 1 mm increase at the end of retention. This change was found to be similar to that observed in the control group, which exhibited an approximately 1.5 mm increase in overbite (Table V).

Occlusal radiography

Of the patients treated, 10 exhibited a 1–1.5 mm wide area of radiolucency in the anterior mid-sagittal region. The radiolucent area was seen mainly in the region of the incisive foramen.

Discussion

Maxillary expansion procedures have been used for over a century. While many designs have been introduced, the acrylic splint expander has been recently developed for rapid maxillary expansion.[20-23] The occlusal acrylic coverage serves as a bite block,

Table IV. The changes in lateral radiographic measurements during different periods.

	Expansion group N = 23			Control group N = 17		
Parameters	T_1-T_0	T_2-T_1	T_2-T_0	T_1-T_0	T_2-T_1	T_2-T_0
Skeletal angular measurements	X±Sx	X±Sx	X±Sx	X±Sx	X±Sx	X±Sx
SNA°	-0,28±0,19	0,18±0,22	-0,10±0,22	0,22± 0,26	0,55±0,19**	0,77±0,23**
SNB°	-0,19±0,21	0,73±0,24 **	0,54±0,19 **	0,29±0,23	0,46±0,19 *	0,75±0,21**
ANB°	-0,10±0,20	-0,55±0,25 *	-0,64±0,27 *	-0,06±0,24	0,08±0,18	0,02±0,21
SN/PP°	0,69±0,31 *	-0,29±0,38	0,40±0,26	0,30± 0,21	-0,32±0,22	-0,02±0,22
SN/MP°	1,23±0,31 ***	-1,43±0,36 ***	-0,20±0,32	-0,92±0,53	-0,07±0,55	-0,99±0,38 *
PP/MP°	0,54±0,40	-1,13±0,40 *	-0,59±0,37	-1,22±0,57 *	0,25±0,63	-0,97±0,38*
Skeletal linear measurements						
N-Me (mm)	3,49±0,43 ***	1,02±0,32**	4,51±0,54 ***	0,97±0,45 *	1,68±0,40***	2,65±0,41***
N-ANS (mm)	1,43±0,22 ***	1,23±0,25***	2,66±0,34 ***	1,33±0,18***	0,64±0,21**	1,97±0,24 ***
ANS-Me (mm)	2,16±0,37 ***	-0,50±0,38	1,67±0,42 ***	-0,38±0,48	1,25±0,50 *	0,87±0,39 *
ANS-Me/N-Me	0,00± 0,00	-0,01±0,00***	-0,01±0,00 **	-0,01±0,00 *	0,00±0,00	-0,01±0,00 *
ANS-PNS (mm)	1,10±0,24 ***	1,21±0,30***	2,32±0,30 ***	1,20±0,27***	0,94±0,37 *	2,14±0,34 ***
Co-A (mm)	0,98±0,39 *	2,27±0,38***	3,25±0,39 ***	2,23±0,43 ***	0,83± 0,45	3,06±0,51 ***
Co-Go (mm)	0,85±0,26 **	1,73±0,39***	2,58±0,40 ***	0,92±0,41 *	1,20±0,37**	2,12± 0,53***
Dentoalveolar measurements						
U1/PP°	2,29±0,75 **	5,98±1,75 **	8,26±1,78 ***	0,86±0,57	1,07±0,53	1,93±0,78 *
L1/MP°	-0,66±0,48	-0,18±0,49	-0,84±0,60	0,41±0,59	-1,08±0,55	-0,67±0,66
U1/L1°	-2,16±0,79 *	-4,67±1,67 *	-6,83±1,79***	-0,04± 0,57	-0,24±0,49	-0,28±0,80
U1-NA (mm)	0,34±0,25	1,72±0,49 **	2,07±0,55 ***	0,17±0,24	0,27±0,27	0,44±0,36
L1-NB (mm)	0,46±0,13 **	-0,25±0,16	0,21±0,22	-0,14±0,15	0,06±0,10	-0,08±0,19
Overjet (mm)	-0,14± 0,31	1,02±0,29 **	0,88±0,49	0,15±0,20	0,25±0,12	0,40±0,23
Overbite (mm)	-0,21±0,40	1,18±0,27 ***	0,97±0,36 *	0,81±0,18 ***	0,60±0,26*	1,42±0,26 ***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

which inhibits the eruption of the posterior teeth during treatment. This enables the appliance to be used in patients with an increased lower facial height.[21] The acrylic occlusal coverage also facilitates the correction of posterior and anterior crossbites by preventing inter-occlusal contact. Acrylic bonded or Haas-type banded appliances have generally been preferred for rapid maxillary expansion, while spring-type expanders, like the QH, titanium expander, or Minne expander, have been used for slow expansion.[9,24,25] However, in the present study, an MSMEA designed with full coverage was used as a slow expander to correct posterior crossbites. The objective was to avoid the possible tipping forces on the deciduous molar teeth from springs or removable plates without occlusal coverage. Furthermore, an SME plate with occlusal coverage used in the mixed dentition has been demonstrated to be useful in correcting midline shifts.[26,27]

The dental and skeletal effects induced through SME therapy were observed in the present study. Maxillary inter-canine and inter-molar widths increased significantly during treatment (5.52 mm and 7.72 mm, respectively) and partially relapsed post-treatment, resulting in a net gain of 4.7 mm and 7.11 mm, respectively. This represented 85% and 91% of the original expansion. This supports the findings of Vargo et al., who investigated the effects of SME (using QH or plate) combined with a mandibular Crozat appliance in the mixed dentition over an observation period of 11 months, without post-treatment retention.[28] It was found that the maxillary inter-canine and inter-molar widths remained stable. The increases in maxillary inter-molar and inter-canine widths found in the present study were greater than those previously reported that involved the use of SME appliances,[12,25] and were very similar to those

Table V. Mean differences in lateral radiographic measurements between the expansion and control groups during different periods.

Parameters	Expansion-Control					
	T_1-T_0		T_2-T_1		T_2-T_0	
Skeletal angular measurements	X±Sx	*p*	X±Sx	*p*	X±Sx	*p*
SNA°	-0,50±0,31	NS	-0,37±0,30	NS	-0,87±0,32	**
SNB°	-0,48±0,32	NS	0,27±0,32	NS	-0,21±0,29	NS
ANB°	-0,02±0,31	NS	-0,63±0,33	NS	-0,66±0,36	NS
SN/PP°	0,39±0,40	NS	0,03±0,48	NS	0,42±0,36	NS
SN/MP°	2,15±0,58	***	-1,36±0,63	*	0,80±0,49	NS
PP/MP°	1,76±0,68	*	-1,38±0,72	NS	0,38±0,54	NS
Skeletal linear measurements						
N-Me (mm)	2,52±0,63	***	-0,66±0,50	NS	1,86±0,72	*
N-ANS (mm)	0,10±0,30	NS	0,59±0,35	NS	0,69±0,45	NS
ANS-Me (mm)	2,55±0,59	***	-1,75±0,62	**	0,80±0,59	NS
ANS-Me/N-Me	0,01±0,00	*	-0,01±0,00	*	0,00±0,00	NS
ANS-PNS (mm)	-0,10±0,36	NS	0,27±0,47	NS	0,18±0,46	NS
Co-A (mm)	-1,25±0,59	*	1,44±0,59	*	0,19±0,64	NS
Co-Go (mm)	-0,07±0,47	NS	0,53±0,55	NS	0,47±0,65	NS
Dentoalveolar measurements						
U1/PP°	1,43±1,00	NS	4,91±2,10	*	6,34±2,19	**
IMPA°	-1,07±0,76	NS	0,90±0,74	NS	-0,17±0,90	NS
U1/L1°	-2,16±1,04	*	-4,43±2,00	*	-6,55±2,20	**
U1-NA (mm)	0,17±0,36	NS	1,45±0,62	*	1,63±0,71	*
L1-NB (mm)	0,60±0,20	**	-0,31±0,21	NS	0,29±0,31	NS
Overjet (mm)	-0,29±0,40	NS	0,77±0,35	*	0,48±0,60	NS
Overbite (mm)	-1,02±0,49	*	0,57±0,38	NS	-0,45±0,47	NS

NS: Non significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

studies which assessed RME.[15,29,30] This could have resulted from the selection of patients exhibiting a mild transverse deficiency in previous SME studies.

Previous longitudinal studies reported that maxillary inter-molar and inter-canine widths increased by approximately 1–2 mm and 1 mm, respectively, between the early mixed (8 years of age) and early permanent dentition (12.5 years of age).[12,31,32] However, control group patients included in the present study showed a lesser increase in maxillary inter-molar width (0.6 mm) and a greater increase in inter-canine width (1.74 mm). Therefore, the transverse deficiency in the control group continued into the posterior region of the permanent dentition but not in the canine region.

Mathews showed that movement of the deciduous molars can affect the position of the erupting premolars.[33] The movement of teeth by means of an expansion procedure appeared to have a remodelling effect on the alveolar bone, since the subsequent eruption of permanent teeth produced a normal transverse relation.[3,8] In the present study, the deciduous first and second inter-molar widths increased by 6.13 mm and 7.27 mm, respectively. After the expansion, the deciduous tooth successors maintained almost the same inter-premolar widths (5.48 mm and 7.11 mm), which confirmed the results of Spillane and McNamara, who assessed RME use during the mixed dentition.[20] However, in the present untreated group, first and second inter-premolar width increases only reached 1.35–1.57 mm. These findings suggest that expansion treatment should be undertaken in the late mixed dentition rather than the permanent dentition.

Mew used a removable appliance for semi-rapid expansion in the mixed dentition and suggested that the continued use of the expansion plate after active expansion during the transitional dentition prevented relapse.[34] Spillane and McNamara used a similar full coverage RME appliance in the mixed dentition followed by an acrylic palatal retainer for a minimum of one year.[20] The maxillary expansion appliance was maintained until the end of the mixed dentition. It was considered that the retention period played an important role in the spontaneous expansion between maxillary permanent second premolars.

The buccal tipping of posterior teeth appeared to be a major factor that contributed to changes in dental arch width.[13] Although Spillane and McNamara reported that no tipping of the molars was observed during RME procedures in the early mixed dentition, alternative studies have reported that molar inclination could increase by 1–24° in RME patients[11,30,35] and by 1.5–11° in patients using SME appliances during the mixed dentition.[13,25,36-38] Excessive molar inclinations have been associated with a mandibular posterior rotation. In the present study, right and left molars exhibited approximately 7.5° of buccal tipping after expansion treatment, but these decreased to 2–2.5° at the end of the retention period, thereby producing an acceptable change. Erdinç et al. found that, after using expansion plates, right and left maxillary molar angulations increased by 3.5° and 4.5° respectively, which was considered very low.[25] However, maxillary inter-molar widths increased by 3.9 mm. It was also found that maxillary molar inclinations remained stable (0–1.4°) in the untreated control group, which provides support for the present findings (0–1.33°).

Rapid and slow maxillary expansion procedures have been related to a loss of buccal alveolar bone resulting from the buccal displacement of the anchorage teeth.[39,40] In a CBCT assessment of alveolar bone after rapid and slow maxillary expansion, Brunetto et al.[41] observed periodontal bone loss on the buccal aspect in both rapid and slow maxillary expansion groups. Higher rates of bone loss occurred in the slow expansion group, which was attributed to the greater bodily movement of the first molars and the possibility of major orthodontic movement with this type of activation. In the present study, CBCT assessments were not undertaken for ethical reasons. However, no periodontal problems were clinically apparent.

In the present study, the inter-molar apical width increased by 2.3 mm, with a further 1 mm increase that continued until the end of the retention period. This straightening likely resulted from minor relapse as well as appliance design, which covered only the palatal cusps while leaving the buccal cusps free. Therefore, the vertical plane angle increased marginally (1.23°) after expansion and returned to its original value during the retention period. Acrylic occlusal coverage prevented tipping and extrusion of the molar teeth, which prevented mandibular posterior rotation. These findings suggested that the MSMEA may be used in patients with increased lower facial height. Hicks stated that removable retention was less satisfactory compared with fixed retention for the stabilisation of the expanded segments.[13] However, it appeared to be a better choice to permit maxillary molar straightening during the retention period.

A clinician faces the problem of determining the optimal magnitude of force that promotes a physiologic separation of the maxilla at the mid-palatal suture, while minimising tooth movement. An SME has been shown to produce radiographic separation of the mid-palatal suture during the primary and mixed dentition stages.[7,9,13,24,36] It has been stated that the ratio of orthopaedic to orthodontic change produced by an SME is variable and depends upon the patient's age, appliance size, stage of dental development, and the amount of active force delivered by the appliance.[42] Previous studies reported orthopaedic expansion to be in the range of 16–64% of the total expansion produced by an SME.[13,24,26,43,44] Frank and Engel, in a study using a QH appliance in the mixed dentition, found a 1.17 mm increase in maxillary base width during the 51 month observation period.[44] A 1.1 mm increase in maxillary base width was observed over 1.2 years.[25] However, a 1 mm increase in the maxillary base was found in the present control group. Expansions of the maxillary base by 2 mm or greater have generally been noted in RME studies.[30] In the present study, it was determined that 45% of all maxillary inter-molar expansion was obtained through inter-maxillary base expansion at the end of the retention period. This finding is in agreement with Krebs' study,[35] which used an RME to achieve a total arch increase that was twice that of the basal maxillary segments. This was consistent with reported findings which indicated that orthopaedic effects occurred following the use of an SME during the early mixed dentition period.[7,9]

Compared with RME effects, changes in lateral cephalometric parameters after an SME have not been thoroughly studied.[35] However, the effects of a bonded or banded RME on the maxilla and mandible have been well investigated in the mixed dentition and confirm the downward and posterior movement of the anterior aspect of the maxilla at anterior nasal spine.[45,46] When the reports of earlier studies conducted on SME were assessed, it was found that there was no clinically significant effect on maxillary translation and a slight increase in mandibular protrusion, in accordance with the present study.[4,47,48] Erdinç et al. did not observe any significant changes in SNA, SNB, ANB, and SN-GoGn angles in the expansion and untreated control groups in the mixed dentition.[25] In the present study, SNA angle remained stable at T_1 in both groups, but increased marginally (0.55°) in the control group during the retention period. SNB angle also showed slight increases in both the expansion and control groups (0.75° and 0.54°, respectively). Although these changes were found to be statistically significant, they are likely to remain clinically insignificant.

It may be concluded that moderate orthopaedic expansion is possible with MSMEA. However, the most significant disadvantage of this expansion appliance therapy is that the results depend largely on individual patient response and compliance.

Summary

Within the limits of this study, the treatment of posterior crossbites with an MSMEA in the mixed dentition provided orthopaedic and orthodontic expansion.

Maxillary inter-molar and inter-premolar widths increased significantly with minimal molar tipping, and most of these increases were maintained until the arrival of the permanent dentition. Maxillary inter-molar and inter-premolar widths increased slightly in the control group during the same period. The maxillary base width increased by 3 mm in the expansion group and by 1 mm in the control group during the total observation period. A retention period that continued until the permanent dentition was useful in maintaining the expansion.

The vertical plane angle increased minimally (1.23°) after the expansion and returned to original values after retention. Acrylic occlusal coverage was effective in maintaining the vertical plane angle and, therefore, it is suggested that this method be considered as the treatment of choice in patients presenting with an increased facial height.

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