ORIGINAL ARTICLE

A prospective long-term study on the effects of rapid maxillary expansion in the early mixed dentition

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Introduction: The aim of this prospective longitudinal clinical study was to evaluate the short-term and long-term changes in dental-arch dimensions in patients treated with the acrylic splint rapid maxillary expander in the early mixed dentition followed by fixed appliances in the permanent dentition. **Methods:** The dental casts of 51 consecutively treated patients (TG) were compared with those of 26 untreated controls (CG) at 3 different times: pretreatment (T1), after expansion and fixed appliance therapy (T2), and at long-term observation (T3). The mean ages for the TG were 8 years 10 months at T1, 13 years 10 months at T2, and 19 years 9 months at T3. Arch widths, arch depth, arch perimeter, and molar angulation were assessed in all subjects at all observation times. T1-T2, T2-T3, and T1-T3 changes were compared statistically in the TG with respect to the corresponding CG. **Results:** Treatment with an acrylic splint RME followed by fixed appliances produced significantly favorable short-term and long-term changes in almost all maxillary and mandibular arch measurements. The amount of change in both maxillary and mandibular intermolar and intercanine widths fully corrected the initial discrepancies. Approximately 4 mm of long-term relative increase in maxillary arch perimeter, and 2.5 mm additional maintenance of mandibular arch perimeter were observed in the TG compared with the CG. **Conclusions:** These results suggest that this protocol is effective and stable for the treatment of constricted maxillary arches, and can relieve modest deficiencies in arch perimeter. (Am J Orthod Dentofacial Orthop 2006;129:631-40)

The treatment of a tooth size-arch length discrepancy by creating additional space in the dental arches is a task that many orthodontists undertake daily. In patients with mild (<3 mm) or severe (>6 mm) crowding, the choice of whether to extract teeth to gain space typically is obvious. In patients with moderate crowding, however, the choice is less clear. The use of an extraction or nonextraction approach to treat these borderline patients has been a topic of controversy throughout the history of the orthodontic profession.

Methods alternative to extractions aimed to relieve tooth size-arch length discrepancies include interproximal reduction of teeth or "stripping," molar distalization, dental expansion, and orthopedic expansion of the maxilla. An orthodontist who decides to alleviate crowding without extractions might choose orthopedic expansion or a combination of these 3 alternatives. An important question then becomes whether the orthopedic expansion is stable in the long term.

Unfortunately, few well-designed long-term studies address the stability of rapid maxillary expansion (RME). Most RME investigations give only short-term results, and many have shortcomings.[1-9] These limitations include the use of small sample sizes, the inclusion of older patients, inadequate descriptions of retention protocols, lack of control subjects, and lack of rigorous statistical analysis.

One long-term study that addresses this issue is that of Moussa et al,[10] who evaluated 55 patients selected randomly from the practice of Andrew Haas, the developer of contemporary RME. The age range at the start of treatment was 8 to 19 years. Three time intervals were analyzed: pretreatment, posttreatment,

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Supported in part by 2 grants from the American Association of Orthodontists Foundation and funds from the Thomas M. and Doris Graber Endowed Professorship, Department of Orthodontics and Pediatric Dentistry, University of Michigan.
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Submitted, July 2004; revised and accepted, October 2004.
0889-5406/$32.00

doi:10.1016/j.ajodo.2005.01.020

and postretention. The treatment included RME followed by fixed appliances. Retention protocols were explained in detail, and the time interval for postretention records was 8 to 10 years, or about 15 years postexpansion. The authors found good stability for maxillary intercanine width (75% maintained), maxillary and mandibular intermolar widths (81% and 100% maintained, respectively), and incisor irregularity. Small increases in arch perimeter and intercanine width still were present in the long term. No further increases in maxillary and mandibular arch lengths were reported at postretention.

Moussa et al,[10] however, did not compare their results with data from untreated controls. This comparison is important because of the naturally occurring reduction in arch dimensions.[11,12] An adequate control group was included in the recent long-term study by McNamara et al,[13] who evaluated arch changes after Haas-type RME and fixed appliance therapy through age 20 years. Treatment with RME followed by fixed appliances induced stable favorable increases in the width of the dental arches and arch depth. Long-term increases of approximately 6 mm in maxillary arch perimeter (80% of initial deficiency) and 4.5 mm in mandibular arch perimeter (full correction of initial deficiency) were observed in patients when compared with untreated subjects. No studies are available on the long-term outcomes of bonded acrylic splint RME therapy.

Evidence shows that the orthopedic effect of RME therapy is influenced by treatment timing.[5,14-16] Skeletal outcomes of greater magnitude and stability can be obtained when the expander is used before the pubertal growth spurt (eg, stages 1 to 3 of the cervical vertebral maturation (CVM) method[16]), with transverse changes shifting to the dentoalveolar level when RME therapy is performed after the pubertal peak (stages 4 to 6 of the CVM method).[15] Unfortunately, little has been published on the effects of RME before the growth spurt or before the development of the permanent dentition.

Spillane and McNamara[11] and Brust and McNamara[12] conducted the first investigations of the effects of RME in the mixed dentition as part of an ongoing prospective clinical trial (Michigan Expansion Study). The initial study described the treatment effects and the short-term stability produced by the acrylic splint expander in the early mixed dentition.[11] Serial dental casts of 162 patients were analyzed to measure arch dimensions preexpansion, immediately postexpansion, and at yearly intervals until the eruption of the first premolars. The average increase in transpalatal width was 5 to 6 mm. At the end of the postexpansion observation period (2.4 years), 80% of the original expansion at the first permanent molars remained. In addition, maxillary dental arches that initially were narrow tended to display greater stability than those that initially were wider. Finally, maxillae with initially more lingually inclined molars tended to retain more expansion than maxillae with initially more buccally inclined molars.

Brust and McNamara[12] continued the investigation of RME in the mixed dentition began by Spillane and McNamara.[11] Brust and McNamara[12] examined a larger sample of patients from the same private practice. Changes in arch width, arch perimeter, and molar angulation were evaluated immediately postexpansion, at first-premolar eruption, and before comprehensive orthodontic treatment. The changes were compared with those occurring over a similar time interval in a control group of 22 untreated subjects from the University of Michigan Elementary and Secondary School Growth Study. A significant amount of stable expansion was achieved in maxillary arches, but changes in the mandibular arches were less stable.

Our investigation is an extension of this ongoing prospective clinical trial of the treatment effects of the acrylic splint RME in the mixed dentition, to assess the long-term stability of dental-arch changes of RME in the early mixed dentition followed by comprehensive orthodontic treatment (phase II). The final evaluation of the patients was an average of 6 years (minimum of 5 years) after phase II treatment, or approximately 10 years after the completion of RME. Serial dental casts of the maxillary and mandibular arches were compared with a control group (CG) of untreated subjects.

SUBJECTS AND METHODS

The patients examined were part of a prospective clinical investigation, the Michigan Expansion Study, of mixed dentition patients who underwent RME in a private faculty practice. A focus of that study is the short-term and long-term treatment effects of RME with acrylic splint expanders in the mixed dentition followed by fixed appliances in the permanent dentition. This study compared the long-term effects of this 2-phase treatment with an untreated group. Active expansion (eg, Schwarz appliance, lip bumper) of the mandibular dental arch was not undertaken during the first phase of treatment.

The treated group (TG) consisted of consecutively treated patients from a group faculty practice; all patients were treated jointly by 3 practitioners. The decision to use RME therapy was based on at least 1 preexisting criterion: crowding, lingual crossbite, esthetics, or tendency toward Class II malocclusion.[17]

The 51 patients (22 male, 29 female) in the TG underwent RME treatment with bonded acrylic splint appliances in the mixed dentition; they were 5 or more years out of phase II treatment. They had a consistent set of characteristics. Before treatment, the following teeth were present: erupted maxillary and mandibular first permanent molars, erupted maxillary and mandibular permanent central incisors, and deciduous second molars. Dental casts were obtained on all patients at 3 times: before treatment (T1), at the completion of phase II treatment (T2), and 5 years or more after the T2 records (T3). Lateral cephalograms at T1 showed stages 1 to 3 of the CVM method (prepeak skeletal maturity[16]); lateral cephalograms at T3 showed stage 5 or 6 of the CVM method (completed or nearly completed active growth). The mean ages were 8 years 10 months at T1, 13 years 10 months at T2, and 19 years 9 months at T3.

Serial dental casts of 26 untreated subjects (18 male, 8 female) were obtained from the longitudinal records of the University of Michigan Elementary and Secondary School Growth Study as the control group (CG). The dental casts were selected to resemble the treated group at each time that records were taken. The criteria for selection at T1 were based on dental development (early mixed dentition) and skeletal maturity (stages 1 to 3 of the CVM method)[16]; T2 criteria were based on dental development and homogeneity of observation interval; T3 criteria were based on skeletal maturity (stage 5 or 6 of the CVM method), a chronological age of 16 years 6 months or older, and a minimum interval between T2 and T3 of 3 years. The mean ages were 8 years 9 months at T1, 14 years 2 months at T2, and 19 years 9 months at T3. The subjects selected from the University of Michigan Elementary and Secondary School Growth Study had predominantly Class I malocclusions; a few tended toward Class II malocclusion; no subject in the control group had a Class III relationship.

The 51 patients underwent RME with bonded acrylic splints (Fig 1) that covered the maxillary first and second deciduous molars and the maxillary permanent first molars.[17] The midline expansion screw was attached to the appliance with a heavy (.045 in) wire framework and routinely was expanded a quarter turn per day until a buccal crossbite was approached. The transverse molar relationship obtained in most instances involved approximating the lingual cusps of the maxillary posterior teeth and the buccal cusps of the mandibular posterior teeth in the transverse dimension.

After expansion, the bonded appliance usually remained in place for an additional 5 months, followed by stabilization with a simple palatal plate with posterior clasps bilaterally. The plate typically was worn full time for 12 months or more and then at night; in a few patients, however, the plate was discontinued after 1 year of retention. A transpalatal arch typically was placed before the loss of the second deciduous molars. In addition, over half of the patients had their maxillary incisors bracketed temporarily for alignment.

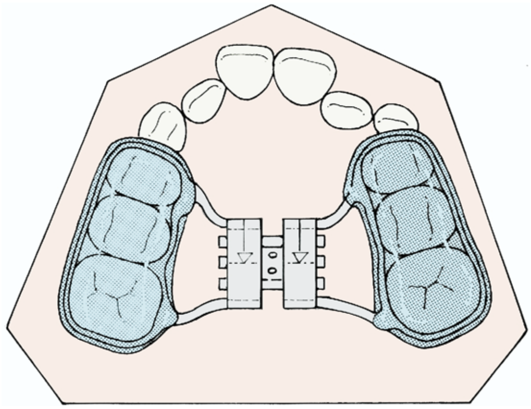

Fig 1. Acrylic splint RME.

After the eruption of the permanent teeth, the patients underwent comprehensive nonextraction orthodontic treatment with preadjusted edgewise appliances (phase II). The transpalatal arch was left in place for the duration of treatment in most patients. After phase II, a positioner usually was used to fine-detail the dentition for 3 weeks to 2 months. Then impressions for invisible retainers typically were taken; the patients were instructed to wear the retainers full time for a year. The patients then were advised to wear the invisible retainers at night for an additional year; then they were encouraged to wear them intermittently at night. Most patients were no longer wearing their retainers at the T3 records.

The dental casts were measured with a digital imaging system (Bioscan OPTIMAS Imaging System, Seattle, Wash). This system was developed specifically for the acquisition, measurement, and storage of data obtained in the earlier study of Brust and McNamara.[12] The methods for image capture and landmark acquisition have been described extensively in previous articles.[11-13,18]

Measurements on dental casts

Arch width was measured at the following teeth: deciduous canines/permanent canines, deciduous first molars/first premolars, deciduous second molars/second premolars, and permanent first molars. Arch width was measured from the lingual point of a tooth to the like point on its antimere (Fig 2) and between the

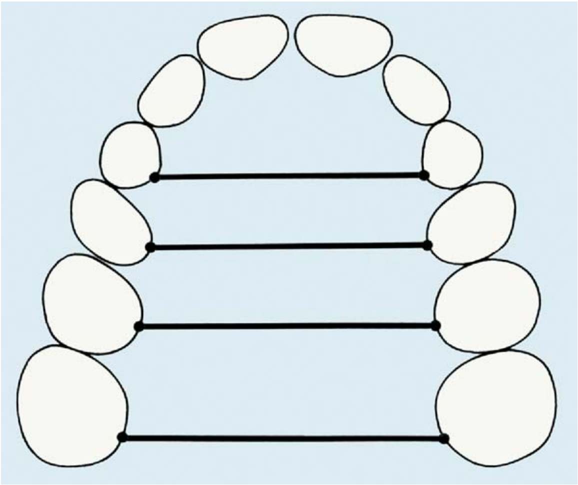

Fig 2. Arch width was determined as distance between lingual landmarks on each posterior tooth. Lingual landmark on maxillary first molars was located at junction of lingual groove with palatal mucosa.

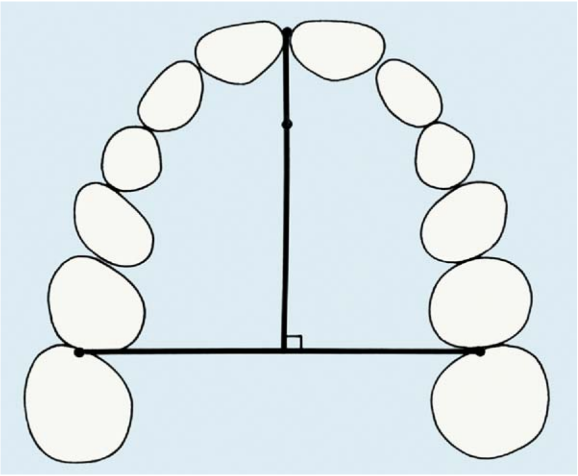

Fig 4. Arch depth was determined by measuring length of perpendicular line constructed from contact point between mesial contact points of central incisors to line connecting contact points between second premolars and first molars.

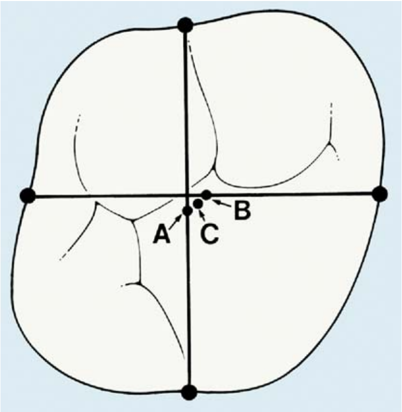

Fig 3. Location of centroid of each posterior tooth was found first by determining midpoint (*A*) of line connecting mesial and distal landmarks. Similar midpoint (*B*) was constructed midway between buccal and lingual landmarks of tooth. Centroid (*C*) was located midway between points A and B.

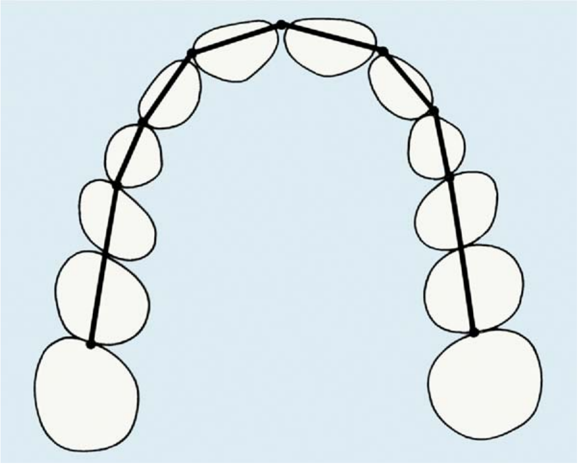

Fig 5. Arch perimeter was determined by constructing line from mesial contact point of 1 molar through mesial and distal contact points of 6 anterior teeth to mesial contact point of opposite molar.

centroids of a tooth and its antimere (Fig 3), as described by Moyers et al[19] and Brust and McNamara.[12]

Arch depth was measured as the distance from a point midway between the facial surfaces of the central incisors to a line tangent to the mesial surfaces of the first molars (Fig 4). Arch perimeter was determined by summing the segments between contact points from the mesial surface of the first molar to the mesial surface of the opposite first molar (Fig 5).

Molar angulation was calculated by measuring the angle of intersecting lines drawn tangent to the mesiofacial and mesiolingual cusp tips of the right and left maxillary and mandibular first molars (Fig 6). Angulation less than 180° indicated that the molars were tipped facially; values over 180° implied lingual tipping.

The error of the method of the digital imaging system was described previously by several investigators.[12,18] In these studies, the error was relatively consistent and within acceptable limits for the analysis

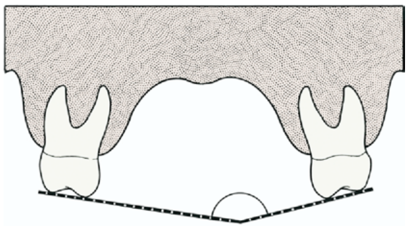

Fig 6. Angulation of maxillary and mandibular first molars was determined by measuring angle of intersection of lines passing through buccal and lingual cusps. Angulation less than 180° indicated that molars were tipped buccally; values over 180° implied lingual tipping.

of serial dental casts. For example, the standard error for the measurement of maxillary intermolar width in these studies ranged from 0.03 to 0.13 mm.

Comparisons between the TG and the CG were performed with the Student *t* test for independent samples. The following statistical comparisons were performed.

- Comparison of starting forms: TG at T1 vs CG at T1.
- Evaluation of treatment effect: T2-T1 changes in TG vs T2-T1 changes in CG.
- Evaluation of posttreatment changes: T3-T2 changes in TG vs T3-T2 changes in CG.
- Evaluation of overall changes: T3-T1 changes in TG vs T3-T1 changes in CG.
- Comparison of final forms: TG at T3 vs CG at T3.

RESULTS

Descriptive statistics for the measurements at T1 and T3, and for the changes T2-T1, T3-T2, and T3-T1, in both groups along with statistical comparisons are reported in Tables I through IV.

At T1, both the maxillary and mandibular dental arches of the patients in the TG were significantly narrower than the corresponding dental arches of the subjects in the CG (Table I). All measurements for maxillary and mandibular arch width (except mandibular intercanine width) and arch perimeters were significantly smaller in the TG than in the CG. The maxillary permanent first molars also had a significantly greater buccal angulation in the TG than in the CG.

The T2-T1 treatment changes with RME followed by fixed appliances produced significantly greater increments in all variables for maxillary and mandibular arch widths (Fig 4) when compared with the controls (Table II). Maxillary arch depth showed significantly greater decreases in the TG with respect to the CG. Significant differences in maxillary and mandibular arch perimeters were found in the TG when compared with the CG. For example, maxillary arch perimeter increased 0.9 mm in the TG but decreased 1.8 mm in the CG. Mandibular arch perimeter decreased less in the TG (–2.4 mm) than in the CG (–4.4 mm). As for the changes in molar angulation (Fig 6), in the TG, the maxillary first permanent molars showed a significant tendency for more lingual inclination.

For the T3-T2 changes in the TG vs the CG, no significant differences in the post-treatment changes were found with respect to the CG, except for maxillary first premolar widths (measured both at the centroid and lingually), which showed significantly greater decreases in the TG, and mandibular intermolar arch width (measured both at the centroid and lingually), which increased in the TG and decreased in the CG (Table II). Mandibular arch width measured at the

Table I. Comparison of starting forms of treated group (TG) and control group (CG)

	TG T1 (n = 51)		*CG T1 (n = 26)*		t *test*
Measure (mm)	*Mean*	*SD*	*Mean*	*SD*	*P*
Maxillary arch width (centroid)					
Intermolar	41.7	2.4	45.2	2.6	‡
Interpremolar (2nd)	37.1	2.3	39.6	2.6	‡
Interpremolar (1st)	32.7	2.1	34.9	2.3	‡
Intercanine	27.7	1.9	29.6	2.2	‡
Mandibular arch width (centroid)					
Intermolar	40.4	1.9	41.8	2.3	†
Interpremolar (2nd)	34.6	1.9	35.7	2.5	*
Interpremolar (1st)	28.6	1.9	29.7	2.2	*
Intercanine	23.3	1.4	23.7	2.0	NS
Maxillary arch width (lingual)					
Intermolar	31.1	2.5	34.8	3.0	‡
Interpremolar (2nd)	27.6	2.4	30.3	2.6	‡
Interpremolar (1st)	24.8	2.2	27.2	2.1	‡
Intercanine	22.8	1.9	24.9	2.5	‡
Manibular arch width (lingual)					
Intermolar	31.1	2.0	32.4	1.9	†
Interpremolar (2nd)	26.6	1.8	27.8	2.3	*
Interpremolar (1st)	23.0	1.9	24.0	2.2	*
Intercanine	18.9	1.4	19.3	2.0	NS
Maxillary arch depth					
1st molar	28.1	1.7	27.9	2.1	NS
Mandibular arch depth					
1st molar	23.7	1.5	24.1	1.7	NS
Maxillary arch perimeter	73.7	3.4	75.9	4.2	*
Mandibular arch perimeter	66.8	3.1	68.1	1.7	NS
Maxillary molar angulation	170.5	5.9	173.4	5.4	*
Mandibular molar angulation	193.4	5.9	191.7	4.8	NS

*$P < .05$; †$P < .01$; ‡$P < .001$; *NS,* not significant.

Table II. Comparisons of changes T2-T1, T2-T3, and T3-T1 between treated group (TG) and control group (CG)

	TG (n = 51)						*CG (n = 26)*						t *test*		
	T2-T1		*T3-T2*		*T3-T1*		*T2-T1*		*T3-T2*		*T3-T1*		*T2-T1*	*T3-T2*	*T3-T1*
Measure (mm)	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*P*	*P*	*P*
Maxillary arch width (centroid)															
Intermolar	4.3	2.0	−0.1	1.2	4.2	2.0	0.9	1.1	−0.2	0.8	0.8	1.5	‡	NS	‡
Interpremolar (2nd)	5.3	2.0	−0.7	1.0	4.9	2.0	1.5	1.4	−0.4	0.9	1.0	1.8	‡	NS	‡
Interpremolar (1st)	5.3	2.0	−0.9	0.9	4.4	2.0	1.6	1.3	−0.3	0.8	1.2	1.4	‡	†	‡
Intercanine	4.0	1.6	−0.6	0.8	3.4	1.6	1.4	1.5	−0.7	0.6	0.7	1.4	‡	NS	‡
Mandibular arch width (centroid)															
Intermolar	1.7	1.5	0.2	1.1	1.9	1.8	0.3	1.2	−0.5	0.5	−0.3	1.4	‡	†	‡
Interpremolar (2nd)	3.2	1.5	−0.7	1.1	2.5	1.8	0.7	1.5	−0.6	0.7	0.0	1.8	‡	NS	‡
Interpremolar (1st)	4.1	1.8	−0.7	1.0	3.4	2.2	0.3	1.2	−0.4	0.5	1.2	1.4	‡	NS	‡
Intercanine	1.5	1.6	−0.6	0.7	1.0	1.7	0.1	1.1	−0.5	0.5	−0.4	1.1	‡	NS	‡
Maxillary arch width (lingual)															
Intermolar	3.4	2.0	−0.6	1.3	2.8	2.0	0.5	1.4	−0.4	0.8	0.1	1.7	‡	NS	‡
Interpremolar (2nd)	4.6	2.3	−0.4	1.2	4.2	2.3	1.2	1.5	−0.1	1.1	1.1	1.6	‡	NS	‡
Interpremolar (1st)	2.8	2.1	−0.6	1.1	2.2	2.1	−0.4	1.4	0.1	1.0	−0.4	1.3	‡	†	‡
Intercanine	2.7	1.6	−1.5	1.1	1.3	1.7	−0.4	1.9	−1.2	1.0	−1.6	1.6	‡	NS	‡
Mandibular arch width (lingual)															
Intermolar	1.1	1.8	0.2	1.1	1.3	1.8	0.2	1.2	−0.5	0.7	−0.2	1.4	*	†	‡
Interpremolar (2nd)	3.2	1.8	−0.5	1.3	2.7	2.0	0.2	1.2	−0.6	0.7	0.5	1.7	‡	NS	‡
Interpremolar (1st)	3.2	2.0	−0.7	1.2	2.5	2.3	1.6	1.2	−0.6	0.9	0.6	1.3	‡	NS	‡
Intercanine	1.3	1.5	−1.2	0.9	0.3	1.6	−0.5	1.4	−0.6	0.9	−1.1	1.4	‡	†	‡
Maxillary arch depth															
1st molar	−2.5	1.8	−0.3	0.7	−2.8	1.7	−1.2	1.4	−1.1	1.2	−2.2	1.7	†	‡	NS
Mandibular arch depth															
1st molar	−2.0	2.0	−0.6	0.8	−2.6	1.8	−1.9	1.5	−1.0	0.8	−2.9	1.6	NS	NS	NS
Maxillary arch perimeter	0.9	3.2	−0.9	1.2	0.0	3.1	−1.8	2.3	−2.0	1.9	−3.8	3.0	‡	†	‡
Mandibular arch perimeter	−2.4	3.4	−1.3	1.4	−3.6	3.4	−4.4	2.5	−1.8	2.3	−6.2	2.5	*	NS	‡
Maxillary molar angulation	6.2	5.6	0.3	4.9	6.4	6.0	3.2	4.1	1.9	5.0	5.1	5.6	*	NS	NS
Mandibular molar angulation	−5.4	6.7	−0.5	4.6	−6.0	7.6	−3.3	5.7	−0.2	4.2	−3.5	5.4	NS	NS	NS

*$P < .05$; †$P < .01$; ‡$P < .001$; *NS,* not significant.

canines (lingually) showed significantly larger decreases in the TG. Significantly smaller decreases were recorded in the TG for changes in maxillary arch depth and maxillary arch perimeter when compared with the CG.

The statistical comparison of the changes in the overall observation period from T1 to T3 in the TG vs the CG for the most part replicated the results of active treatment changes (T1-T2) (Table II). For example, by contrasting the overall change in maxillary arch perimeter in the TG (0.0 mm) with the same measurement decreases in the CG (–3.8 mm), 3.8 mm more arch perimeter was recorded in the TG. In the mandibular arch, arch perimeter decreased –3.6 mm in the TG and –6.2 mm in the CG, leading to a difference of 2.8 mm more in the TG.

No statistically significant difference was found between the final forms of the TG and the CG (Table III). The only exception was a slightly larger width in mandibular arch measured at the second premolars (centroid) in the TG with respect to the CG.

DISCUSSION

The goal of this longitudinal prospective clinical study conducted in a private practice was to assess the changes in arch dimensions in mixed-dentition patients who were treated with RME followed by fixed appliances compared with those observed in an untreated CG. An original feature of this investigation was the use of acrylic splint RME in patients during the mixed-dentition phase. All subjects in the TG initially had significant constriction of the maxillary arch with respect to controls, associated with variable degrees of crowding. The TG required RME to improve the

Table III. Comparison between treated group (TG) and control group (CG) at T3

	TG T1 (n = 51)		CG T1 (n = 26)		t test
Measure (mm)	Mean	SD	Mean	SD	P
Maxillary arch width (centroid)					
Intermolar	45.8	2.6	45.9	3.0	NS
Interpremolar (2nd)	42.0	2.2	40.6	3.1	NS
Interpremolar (1st)	37.1	1.9	36.0	2.5	NS
Intercanine	31.0	1.8	30.5	2.2	NS
Mandibular arch width (centroid)					
Intermolar	42.3	2.5	41.5	2.8	NS
Interpremolar (2nd)	37.1	2.1	35.7	3.0	*
Interpremolar (1st)	31.9	1.9	30.9	2.1	NS
Intercanine	24.2	1.4	23.4	1.8	NS
Maxillary arch width (lingual)					
Intermolar	33.9	2.4	34.9	3.0	NS
Interpremolar (2nd)	31.7	2.1	31.4	3.0	NS
Interpremolar (1st)	26.9	1.8	26.6	2.5	NS
Intercanine	24.0	1.5	23.6	2.6	NS
Mandibular arch width (lingual)					
Intermolar	32.5	2.4	32.2	2.6	NS
Interpremolar (2nd)	29.3	2.2	28.4	2.9	NS
Interpremolar (1st)	25.4	1.9	24.7	1.9	NS
Intercanine	19.0	1.3	18.2	1.7	NS
Maxillary arch depth					
1st molar	25.3	1.8	25.7	2.2	NS
Mandibular arch depth					
1st molar	21.1	1.6	21.2	2.2	NS
Maxillary arch perimeter	73.7	3.6	72.1	5.8	NS
Mandibular arch perimeter	63.2	3.4	62.0	4.1	NS
Maxillary molar angulation	177.0	4.3	178.5	5.8	NS
Mandibular molar angulation	187.4	5.3	188.2	6.0	NS

*$P < .05$; *NS*, not significant.

transverse arch dimension before fixed appliance treatment. No active expansion of the mandibular arch (eg, Schwarz appliance, lip bumper) occurred during the mixed dentition.

The evaluation of the active treatment effects after RME and fixed appliance therapy showed significantly larger values in all arch dimensions relative to the CG. From T1 to T2, maxillary intermolar and intercanine widths demonstrated average increments of about 4 mm, whereas the increases in mandibular arch widths ranged between 1.0 and 1.5 mm.

All subjects in both groups had their second deciduous molars at the beginning of the study. With regard to the actual change in arch perimeters, the 0.9-mm increase in maxillary arch perimeter was associated with a loss (–2.4 mm) in mandibular arch perimeter at the end of phase II. By taking into account the normally occurring decreases in arch perimeter observed in the CG during the same time interval (–1.8 and –4.4 mm for the maxillary and mandibular arches, respectively), maxillary arch perimeter in the TG was 2.7 mm larger relative to the CG at the end of fixed appliance therapy; mandibular arch perimeter was 2.0 mm larger in the TG as well. As for the changes in maxillary arch depth, a greater decrease in the TG was found with respect to the CG (–2.5 vs –1.2 mm).

During the posttreatment period, very slight changes occurred in arch width measurements in both the maxilla and the mandible of the TG. Furthermore, no relapse tendency was observed in arch perimeter after active treatment. On the contrary, significantly smaller decreases in maxillary arch perimeter were detected in the TG than in the CG, associated with significantly smaller decreases in maxillary arch depth in the TG.

At the end of the overall observation period, the increase in maxillary intermolar width for the TG was 4.2 mm, which was 3.5 mm larger than in the CG (Table IV). Mandibular intermolar width showed an actual increase of 1.9 mm in the TG; this was 2.1 mm larger than the corresponding measurement in the CG. The relative change in arch perimeter in the TG vs the CG was 3.8 mm for the maxilla and 2.5 mm for the mandible. However, these apparent increases in arch perimeter were due in great part to the negative changes in the CG in the long term. In a time interval of 11 years that covers both the mixed and permanent dentitions, average decreases of –3.8 and –.2 mm were observed in untreated subjects in maxillary and mandibular arch perimeters, respectively.

The results of this study extend the information about modifications in arch perimeters in growing subjects analyzed previously by Spillane and McNamara[11] and Brust and McNamara.[12] Most obvious are the conspicuous losses that can be expected in both arches from childhood through young adulthood. The loss in arch perimeter, shown by the CG, must be ascribed mainly to the exfoliation of the second deciduous molars in both arches and their replacement with smaller second premolars.

On a separate note, the behavior of arch depths in both the treated and untreated samples should be elucidated. Consistent losses in both maxillary and mandibular arch depths were recorded during active treatment and in the posttreatment periods. Interestingly, the amount of loss in maxillary arch depth in the TG was greater than that observed in the CG. Most of this difference occurred during the active treatment period when the loss in arch depth for the TG (–2.5 mm) was more than twice that of the CG (–1.2 mm). The active retraction of the anterior teeth by way of

Table IV. Net changes in treated group (TG) compared with control group (CG)

	Maxillary arch width (centroid)		Mandibular arch width (centroid)		Maxillary arch perimeter	Mandibular arch perimeter
	Intermolar	Intercanine	Intermolar	Intercanine		
TG (n = 51)						
T1-T2	4.3	4.0	1.7	1.5	0.9	−2.4
T2-T3	−0.1	−0.6	0.2	−0.6	−0.9	−1.3
T1-T3	4.2	3.4	1.9	0.9	0.0	−3.7
CG (n = 26)						
T1-T2	0.9	1.4	0.3	0.1	−1.8	−4.4
T2-T3	−0.2	−0.7	−0.5	−0.5	−2.0	−1.8
T1-T3	0.7	0.7	−0.2	−0.4	−3.8	−6.2
Net changes						
T1-T2	+3.4	+2.6	+1.4	+1.4	+2.7	+2.0
T2-T3	+0.1	+0.1	+0.7	−0.1	+1.1	+0.5
T1-T3	+3.5	+2.7	+2.1	+1.3	+3.8	+2.5

fixed appliances probably accounted for most of this slight reduction in arch depth.

At T3 (Table III), when all subjects in both samples had ended or nearly finished their active growth periods, the initial deficiencies in arch width and arch perimeter in the TG with respect to the CG were corrected completely. From a clinical standpoint, the amount of correction in maxillary intermolar and intercanine widths and in maxillary arch perimeter equaled the initial discrepancies.

When analyzing the literature, a comparison of the outcomes of this study can be performed at least indirectly with the results of Moussa et al[10] and directly with those of McNamara et al,[13] who used a similar measurement protocol as that of our study. The latter group used the same measuring equipment (digital imaging system) and the same landmarks for analysis as we did. Moussa et al,[10] however, measured changes in dental-arch dimensions differently (a 2-pointed caliper was used to measure the dental casts directly), and the definitions of arch width, arch perimeter, and arch length included slightly different landmarks than those used here; thus a direct comparison between the 2 studies cannot be made. Both previous investigations evaluated treatment protocols that included a tooth/tissue-borne device for RME (Haas expander), whereas our study evaluated an acrylic splint expander bonded to the teeth.

The treated group of Moussa et al[10] showed a mean increase of 6.7 mm in maxillary intermolar width due to active intervention—a value greater than that found in the study of McNamara et al[13] and in this study for the same measurement (4.4 mm in both studies). The increases in maxillary intercanine width in both previous studies were similar to the increase reported here (about 4.0 mm). As for the mandibular arch, Moussa et al[10] found an increase of about 2 mm for intermolar width, similar to the value reported here (1.7 mm) and in contrast to the value reported by McNamara et al[13] (1.0 mm). All 3 studies agreed on a 1.5-mm increase in mandibular intercanine width over the long term. Similar changes for the widths of both dental arches were assessed in the 3 studies for the overall observation period (T3-T1).

As for the measurement for maxillary arch perimeter, in this study, the overall increase during active treatment was minimal (0.9 mm) when compared with the increases reported by Moussa et al[10] (4.1 mm) and McNamara et al[13] (6.3 mm). On the other hand, the significant decreases in maxillary arch perimeter during the posttreatment period in the previous studies (–2.5 to –3.5 mm) were not observed in our study. In the overall observation period, although the previous articles indicated positive increases for maxillary arch perimeters, this study did not find a change for this measurement. Through the assessment of the loss in the CG (–3.8 mm), the final outcome indicates actual maintenance of 3.8 mm in maxillary arch perimeter (Table IV), a value that is considerably less than that reported by McNamara et al[13] (6.0 mm). The absence of untreated controls in the study by Moussa et al[10] does not allow a direct comparison with the other 2 investigations in terms of clinical significance of the values for changes in arch perimeters.

The relatively smaller amount of increase in maxillary arch perimeter observed in this study with respect to the one by McNamara et al[13] can be explained by at least 2 clinical aspects. The first difference between the 2 studies (which might be of significant importance to the clinician) relates to the amount of activation of the expansion screw during the active treatment phase: 10.0 to 10.5 mm with the Haas-type of RME[13] and 7 to 8 mm (on average) in this study. It might be that more aggressive overcorrection of the transverse skeletal discrepancy in the mixed dentition is indicated, just as Haas suggested when using his appliance. The concept of overcorrection might be as important in RME therapy as it is in extraoral traction treatment for Class II malocclusion[17] or facial mask/RME therapy for Class III malocclusion.[20]

A second explanation concerning the smaller amount of maxillary arch perimeter noted in the TG relative to the CG in this study is linked to the overall loss in maxillary arch depth that we observed (–0.6 mm) in comparison with the actual increase in the same measurement in the study by McNamara et al[13] (2.9 mm). The net difference between the 2 studies is a lack of increase in maxillary arch depth of about 3.5 mm in subjects treated with the acrylic splint RME with respect to subjects treated with the Haas-type of RME.[13] The timing for RME,[5,14,15] however, more than the type of appliance probably accounted for different results for maxillary arch depth. The average age when expansion was performed in our study was 8 years 10 months, whereas it was 12 years 2 months in the sample analyzed by McNamara et al.[13] The use of RME in the early mixed dentition requires a significantly longer and more critical period of therapeutic management of space maintenance during the exfoliation of the posterior deciduous teeth.

Mandibular arch perimeter decreased during active treatment in the TG, followed by a supplementary decrease during the posttreatment period; this produced a decrease in the overall observation period of –3.7 mm. This value apparently is much less promising with respect to those reported in previous investigations. Both Moussa et al[10] and McNamara et al[13] found substantial increases in mandibular arch perimeter during active treatment followed by decreases during the posttreatment period, with a final overall increase of about 1.5 mm in the study by McNamara et al[13] and a final overall decrease of about 0.5 mm in the sample of Moussa et al.[10] An obvious explanation lies in the stage of dental development of the subjects monitored in the 3 studies. All patients and subjects in our study were in the mixed dentition. Because the subjects in the other studies were on average 12 years of age at the time of initial records, many if not most of them were in the permanent dentition.

The considerable amount of loss in mandibular arch perimeter in the CG during the overall observation period (–6.2 mm) produced a maintenance of 2.5 mm in arch perimeter in the TG in this study (Table IV), an amount that is more than the half of the amount reported by McNamara et al[13] (4.5 mm). However, our patients did not undergo active orthodontic expansion in the mandibular arch in the mixed dentition (eg, Schwarz appliance, lip bumper), presumably because they were judged clinically to have sufficient arch perimeter in the mixed dentition to allow for the unimpeded eruption of the permanent mandibular teeth without active intervention in that arch.

When compared with the only other study that includes observations on untreated controls in the long term,[13] the results of our study suggest that treatment with acrylic splint RME in the mixed dentition leads to less favorable amounts of relative increase in the perimeter of both arches in comparison with controls. Nevertheless, the relative increases in intermolar and intercanine widths in both the maxilla and the mandible were similar in the 2 studies, even with a considerably smaller amount of activation of the RME screw in the sample evaluated here in comparison with those treated with the Haas-type expander.[10,13]

This favorable outcome in the transverse dimension of both arches probably should be ascribed to the different treatment timing of the expansion protocols (early mixed dentition in this study and late mixed dentition or early permanent dentition in the study by McNamara et al[13]). It has been shown that when RME is performed during the early developmental phases, treatment outcomes are more skeletal and more stable over the long term.[15] RME in the early mixed dentition appears to be indicated for an effective and stable correction of transverse deficiencies of the dental arches, whereas the effectiveness of this treatment approach might be more critical if it aimed to increase arch perimeter.

CONCLUSIONS

Therapy with an acrylic splint RME in the early mixed dentition followed by fixed appliances in the permanent dentition can be considered an effective treatment option to correct transverse deficiencies of both maxillary and mandibular arches when evaluated in the long term. No active expansion of the mandibular dental arch was undertaken during the mixed dentition. RME followed by fixed appliances can also be considered an option to relieve modest tooth size-arch length discrepancies. Approximately 4 mm of long-term relative increase in maxillary arch perimeter and 2.5 mm additional maintenance of mandibular arch perimeter were observed in the TG when compared with the CG.

We thank Elvis L. Evans for modifying the digital imaging system for use in this study.

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