

Maxillary Adaptation to Expansion in the Mixed Dentition

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This study presents the findings of 162 patients who underwent rapid maxillary expansion during the early mixed dentition. Maxillary changes were evaluated through the analysis of serial dental casts. Arch dimensions were measured pre-expansion, immediately post-expansion, and at yearly intervals until the eruption of the first premolars. The expansion was effected with an acrylic rapid maxillary expansion appliance bonded to the posterior teeth for 5 to 6 months. A simple retention protocol was used post-expansion. The average increase in transpalatal width was 5 to 6 mm. During the post-expansion period, most of the arch width increases were maintained. For example, 90.5% of the original expansion at the first permanent molars remained after the first year, with slightly less overall expansion (80.4%) evident at the end of the observation period (2.4 years postexpansion). Maxillary dental arches that initially were narrow tended to retain a greater percentage of the achieved expansion than those with initially wider arch dimensions. In addition, maxillae with initially more lingually-inclined molars tended to retain more expansion than maxillae with initially more facially-inclined molars. Palatal vault height decreased very slightly during treatment, but returned to pretreatment values one year after expansion and increased slightly during subsequent time intervals. The results of this study indicate that the majority of increased arch dimensions in patients produced by early orthopedic expansion of the maxilla are maintained at the end of the transitional dentition.

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One frequently encountered problem in clinical practice is a discrepancy between patient tooth size and arch size, a relationship that is manifested as dental protrusion or more frequently as dental crowding. In the permanent dentition, discrepancies between tooth size and arch size usually are treated in one of three ways: extraction,¹⁻⁴ interproximal reduction,⁵⁻⁸ or arch expansion.⁹⁻¹⁴ These treatments have been shown to be effective in ado-

lescent patients depending upon the etiology of the crowding or protrusion problem.

During the last two decades, an increasing number of younger patients have been referred for orthodontic treatment. This change in referral pattern in part may be a reflection of the growing interest in prevention evident within the general population, as well as the result of a heightened awareness among dental practitioners of the possibilities of orthodontic and orthopedic treatments that can be used in young patients. Mixed dentition patients are referred most frequently on the basis of concerns about "crowding," as this potential problem is recognized easily by the family as well as by dental and medical professionals.

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Supported in part by grants from the American Association of Orthodontists and the American Association of Orthodontists Foundation, St Louis, MO.

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1073-8746/95/0103-0007\$5.00/0*

Methods of Treatment in the Mixed Dentition

The variety of treatment alternatives for managing a tooth-size/arch-size discrepancy in the

mixed dentition is similar in many respects to those protocols used to correct this problem in the permanent dentition. Comparable mixed dentition treatment protocols include serial extraction and orthopedic expansion, with interproximal reduction typically being reserved for permanent dentition patients. In addition, space maintenance procedures also can be used to take advantage of the size differences between the primary teeth and their successors (ie, leeway space).

Space Management

A relatively simple, yet frequently overlooked, protocol that can be used for the patient with mixed dentition is space management, a treatment scheme that includes the maintenance of leeway space. Among others, Moyers and colleagues¹⁵ have shown that an average of 2.5 mm of space per side can be gained in the mandibular arch, and about 2 mm per side in the maxillary arch, if permanent first molar position is maintained during the transition to the permanent dentition. Gianelly¹⁶ hypothesizes that tooth-size discrepancies can be resolved in 85% of all mixed dentition patients using a non-extraction approach that includes the placement of one or more holding arches in the late mixed dentition.

Appliances used in space management include lingual arches to stabilize either mandibular or maxillary molar positions during the transition from the deciduous to the permanent dentition. A transpalatal arch¹⁷ also can be used either as a passive appliance to maintain the position of the upper molars or as an active appliance to rotate and torque these teeth, often improving the sagittal molar relationship in the process. It should be noted, however, that there is wide variation in tooth size among patients,¹⁸ and that each patient must be evaluated radiographically to determine the relative size of the second deciduous molars and their successors. In addition, if space maintenance is to be used to resolve an arch length discrepancy, the leeway space cannot be used to correct a disparity in interarch molar relationship (eg, by "slipping anchorage").

Serial Extraction

In instances of more severe crowding, a logical diagnostic decision may be to extract teeth. Serial extraction has been recognized as an acceptable method of treatment for over 60 years. This protocol began in Europe in the 1930s, and since then has been advocated by a number of clinicians, including Hotz,^{19,20} Kjellgren,²¹ Dewel,²²⁻²⁴ and Dale.^{25,26} Ringenberg²⁷ stated in a critical review of serial extraction protocols that these types of extraction sequences should be used in those patients who have a tooth-size/arch-size discrepancy of 7 mm or greater, while Proffit²⁸ cites a predicted discrepancy of 10 mm or greater as an indication for serial extraction. In addition, Graber²⁹ cautioned against using these protocols in patients with substantial skeletal discrepancies or in those who have bialveolar protrusion or retrusion.

McNamara and Brudon¹⁷ stated that a primary factor to consider when making a treatment decision concerning serial extraction is the size of the individual permanent teeth. A serial extraction protocol is indicated in instances in which teeth are abnormally large and the dimensions of the dental arches (eg, the transpalatal width between the upper first molars) are within normal values. For example, large tooth size can be determined by comparing the aggregate width of the upper or lower four permanent incisors (or both) of an individual patient to ethnic- and gender-matched standards.^{15,30} Large tooth size is an indication for serial extraction rather than expansion, because of the obvious difficulty in accommodating relatively oversized teeth within averaged-sized dental arches. If nonextraction treatment is attempted in these types of patients, unfavorable changes in facial profile may result and the treatment outcome may be unstable.

Orthopedic Expansion

An alternative approach to the treatment of crowding in the mixed dentition is orthopedic expansion. The cornerstone of this treatment approach is rapid maxillary expansion (RME), an orthopedic procedure that has been shown

not only to separate the midpalatal suture, but the circumzygomatic and circummaxillary sutural systems as well.³¹ New bone is deposited in the areas of expansion, so that the integrity of the mid-palatal suture is usually reestablished within 3 to 6 months.¹⁰ In addition to crossbite correction, the RME procedure can increase maxillary arch perimeter, as has been shown by Atkins and colleagues³² who reported that every millimeter of posterior expansion produces about 0.7 mm of additional arch perimeter. The RME procedure either can be used alone or in combination with adjunctive treatments that produce orthodontic tooth movement (eg, fixed appliances, lip bumpers, utility arches, Schwarz appliances).

The RME procedure has a long history, dating back to the middle of the last century,³³ and has been accepted as a routine treatment modality for over 30 years.^{9-14,35-39} This orthopedic treatment, however, generally was not used routinely in mixed dentition patients until the development of bonding technology. The acrylic splint expander, developed⁴⁰⁻⁴⁴ during the last 20 years, has become a routine method of achieving maxillary arch expansion in primary and mixed dentition patients.^{17,45,46}

The acrylic splint expander not only affects the transverse dimension, but also can produce changes in the vertical and anteroposterior dimensions as well.¹⁷ The occlusal acrylic coverage, typically made from 3 mm-thick splint Biocryl (Great Lakes Orthodontic Products, Tonawanda, NY), acts as a bite block to inhibit the eruption of the posterior teeth during treatment, thereby making possible the use of this appliance in patients with increased lower anterior facial heights.¹⁷ The acrylic occlusal coverage also opens the bite anteriorly, facilitating the correction of anterior crossbites.

Although there is extensive literature on the treatment effects of the RME procedure, only two studies have investigated the effects produced by the acrylic splint expander with posterior occlusal coverage. Sarver and Johnston⁴⁶ conducted a cephalometric study on twenty patients, whose average age at the beginning of treatment was 10.8 years. The effects of acrylic-splint RME treatment for these patients were compared to the findings from

60 patients who wore the Haas-type expander and who previously had been studied by Wertz.¹² A decrease in the vertical displacement of the maxilla was noted in the bonded appliance group. Sarver and Johnston⁴⁶ suggested that the inferior displacement of the maxilla may be limited during treatment by the forces placed on the dentition by the elevator musculature and by the forces associated with the stretch of other soft tissues. In the bonded expander group, a slight superior movement of the posterior aspect of the palatal plane also was noted, as was a downward and posterior movement of the anterior aspect of the maxilla at the anterior nasal spine.

Mossaz-Joëlon and Mossaz⁴⁷ compared unbanded and bonded spring-loaded expander as methods of slow maxillary expansion. Patients had metallic implants placed in craniofacial structures before treatment. Lateral and posteroanterior cephalograms and serial dental casts were used to evaluate the treatment results obtained in two groups of five juvenile patients each. The researchers reported that the relative amount of skeletal and dental movements equaled results obtained with rapid maxillary expansion. No statistically significant differences were found between unbanded and bonded appliances with regard to dental and skeletal expansion or relapse.

Purpose

Although the RME procedure has been studied extensively in adolescents and to a lesser extent in adults and mixed dentition patients, the treatment effects produced by the bonded acrylic splint expansion appliances on the dental arches of mixed dentition patients have not been investigated yet. The purpose of this study, therefore, is to present initial data from an on-going clinical investigation of the RME procedure in mixed dentition patients. The current investigation quantifies the amount of maxillary expansion resulting from the RME procedure and the changes in the maxilla at specific post-expansion intervals. The relationship between the stability of arch expansion and initial arch width, age at start of treatment, gender, presence of initial posterior crossbite, amount of expansion, and length of retention also will be considered.

Patients and Methods

Sample

A major focus of this initial investigation was assembling the data base. For the present investigation, all mixed dentition patients who had the RME procedure during a 5-year period in the private practice of one of the authors (J.A.M.) were potential participants in the study. All patients under consideration had tooth-size/arch-size discrepancies diagnosed in the early mixed dentition and were treated for this problem, at least in part, by rapid maxillary expansion. The parent sample consisted of 224 consecutively treated patients.

Well-defined exclusionary rules were applied to the parent sample to establish a defined treatment group. No patients were excluded from the study based on the success of treatment; however, patients became ineligible for one or more of the following reasons: unerupted maxillary first permanent molars before treatment (25 cases eliminated); not all maxillary first and second deciduous molars and deciduous canines present before treatment (14 cases eliminated); absence of immediate postexpansion records (20 cases eliminated); and distorted dental cast (3 cases eliminated).

The final treatment sample for this study ultimately consisted of 162 subjects (73 males and 89 females) almost all of whom were white. The average age of the subjects when pretreatment records were collected was 8 years 8 months (± 16 months). Thirty-seven subjects exhibited unilateral crossbites and six subjects, bilateral posterior crossbites; the remaining 119 subjects had no posterior crossbites.

None of the patients had orthodontic treatment in the maxillary arch prior to undergoing RME treatment. Although it was anticipated that virtually all patients would have a final phase of fixed-appliance therapy after the eruption of the permanent teeth, the interval considered in this investigation included the phase of treatment during which the expansion appliance was worn and the subsequent interval during the mixed dentition phase until the eruption of the first premolars was completed (2.4 years postexpansion).

Treatment Protocol

The RME protocol used on these patients is described in detail in McNamara and Brudon.¹⁷ The bonded acrylic splint expander was activated one-quarter turn per day for 28 to 42 days until the appropriate amount of expansion had been achieved, as judged by the upper lingual cusps of the maxillary posterior teeth approximating the lower buccal cusps of their antagonists. The appliance was left in place for 4 to 5 months following cessation of expansion to allow for the reorganization of the midpalatal and circummaxillary sutural systems. About half of the sample patients had brackets placed on the upper four anterior teeth to achieve incisal alignment. Immediately after appliance removal, an acrylic palatal retainer with arrow clasps on either side of the second deciduous molars was applied and worn by the patient for a minimum of 1 year.

Data Collection

Records are gathered prolectively⁴⁸ on all participants in the Ann Arbor Expansion Study, an ongoing clinical investigation of the treatment effects produced by rapid maxillary expansion in the mixed dentition. Accordingly, all subjects have records taken at specific treatment intervals, regardless of the outcome of treatment. Specifically, each patient has study models taken pretreatment, immediately post-treatment, at 6-month intervals until the beginning of the final phase of fixed appliance therapy, at the end of treatment, and then every 1 or 2 years thereafter. Cephalograms have been (or will be) obtained before and after major phases of treatment (ie, Phase I, Phase II) and at five years posttreatment as well.

For the purpose of the present investigation, study models taken before expansion (T_1), immediately post-expansion (T_2), one year postexpansion (T_3), two years postexpansion (T_4), and after the eruption of the first premolars (T_5) were evaluated. According to the study's exclusionary rules, all 162 subjects had study models taken pre- and posttreatment. Because of the longitudinal nature of the overall study, however, there was a decreasing number of subjects beginning at T_3

(124 subjects), T_4 (94 subjects), and T_5 (84 subjects). The average post-expansion time interval of the T_5 records was 2.4 years.

Measurement of Arch Dimensions

Measurement of arch width, palatal height, and palatal depth were obtained on the maxillary dental casts available for each series. Serial maxillary dental casts were measured directly by one investigator (L.M.S.) who used a digital caliper calibrated to 0.1 mm. Photocopying or digital imaging of the dental casts was not used.

Transpalatal Width

Transpalatal width was measured between the deciduous canine/canines, first deciduous molar/first premolar, second deciduous molar/second premolars, and the first permanent molars. Dental cast data were not recorded for teeth in the process of initial eruption and exfoliation or for teeth that were severely tipped, rotated, or carious, for teeth that were ectopically erupted, or for teeth that obviously were distorted in the study model. Both lingual dental and facial alveolar measures, as described by McDougall and co-workers,⁴⁹ were obtained.

Lingual measures. The distances between antimeres were measured from the cervical margin of one tooth at the point of greatest convexity to the same point on its counterpart on the opposite side of the arch. When the dimension between first permanent molars or second deciduous molars were measured, landmarks at the junction point of the lingual groove and the gingival margin were used.

Alveolar measures. The distances between the facial alveolar processes overlying the first deciduous molar/first premolars regions (anterior alveolar measure) and the first permanent molar region (posterior alveolar measure) were determined by measuring reference points located 4.0 mm below the free gingival margin at approximately the same position mesiodistally as were those points used to establish the lingual landmarks for the deciduous first molars/first premolars and permanent first molars.⁴⁹

Other Measures

Palatal height. Palatal height was measured as the distance from the functional occlusal plane at the level of the maxillary first molar to the palatal raphe.¹⁵

Arch depth. Dental arch depth was measured as the distance from a point between the central incisors perpendicular to a tangent touching the mesial surfaces of the maxillary first molars.¹⁵

Analysis of Subgroups

Postexpansion changes in arch width were analyzed for subgroups of the treatment sample to determine correlations between pretreatment variables and postexpansion stability.

Initial arch width. The treated sample was divided into "narrow" and "wide" subgroups to determine if maxillae that were narrower at the beginning of treatment retained more expansion than those that were wider initially. Patients with the 20 widest arches and the 20 narrowest arches were compared. The groups were divided on the basis of initial transpalatal width between the maxillary first primary molars. This measure was chosen for two reasons. At T_5 time, the first premolars were fully erupted and were thought to be a reliable indicator of overall retained expansion because these teeth remained unerupted during the expansion procedure and thus were affected only indirectly by the treatment. In addition, the distance between the deciduous first molar/first premolar appeared to be more sensitive to changes in arch form than was the distance between the maxillary permanent first molars, particularly in instances of tapered maxillary arches.

Initial tooth inclination. In order to determine if lingually inclined buccal segments retain more expansion than those that were more facially inclined, the treated sample was divided into subgroups, based on the difference between lingual dental and facial alveolar measures at the level of the maxillary first permanent molar. A ratio of pretreatment, consisting of first molar lingual dental and facial alveolar arch widths, was made. The 20 subjects with the highest ratio (lingually inclined teeth) were compared with the 20 subjects with the smallest ratio (facially inclined teeth).

Other comparisons. Other factors were correlated with the stability of the expansion, including age at start of treatment, gender, the presence of an initial crossbite, the amount of the expansion, and the length of time postexpansion.

Statistical Analysis

Groups were compared by completely randomized *t*-tests, whereas the significance of changes across time was determined by paired *t*-tests. The association between pretreatment variables was evaluated by the Pearson product-moment correlation. Multiple regression and correlation were employed to test the working hypothesis that the amount of stable molar expansion at T_3 , T_4 , and T_5 times can be predicted from measures evaluated at T_1 time. Independent variables considered included age at start of treatment, gender, pretreatment crossbite, amount of expansion obtained, and postexpansion time. For all tests of statistical significance, the type I error rate was set at .05. Given the present sample size, therefore, correlations of $r = .7$ or greater were considered significant.

Error Study

Measurements were repeated on 50 randomly selected sets of casts. The error standard devi-

ation for each dimension was calculated from the double-determinations with the aid of Dahlberg's formula:

$$SD_e = \sqrt{\sum d^2/2N},$$

where d is the difference between each of the 50 replications and N is the number of subjects. For the measures used here, the error standard deviations were about 0.2 to 0.3 mm.

Results

Treatment Effects Produced by RME

Arch Width

Significant increases ($P < .001$) in arch width were seen when preexpansion (T_1) and postexpansion (T_2) measurements were compared (Table 1). Mean transpalatal width increases at T_2 time ranged from 4.9 mm at the canines to 6.0 mm at the first molars, indicating that more expansion occurred posteriorly than anteriorly. No sexual dimorphism was observed. A comparison of the differences between the lingual dental measures and the facial alveolar measures indicated that the teeth anchoring the expander were moved bodily rather than tipped (Table 1).

Palatal Height

Palatal height remained relatively unchanged postexpansion (Table 2). The mean pretreat-

Table 1. Transpalatal Width Preexpansion (T_1) and Postexpansion (T_2)

| Time | Distance | N | Mean (mm) | SD (mm) | Minimum (mm) | Maximum (mm) |
|-------------|--------------------|-----|-----------|---------|--------------|--------------|
| T_1 | 6-6 | 162 | 32.4 | 2.8 | 23.5 | 40.7 |
| | E-5 | 161 | 28.9 | 2.6 | 22.4 | 34.7 |
| | D-4 | 160 | 25.0 | 2.2 | 19.4 | 30.7 |
| | C-3 | 153 | 22.8 | 2.2 | 17.6 | 28.3 |
| | Posterior Alveolar | 162 | 53.7 | 2.9 | 46.4 | 61.7 |
| T_2 | Anterior Alveolar | 162 | 41.8 | 2.3 | 49.6 | 49.6 |
| | 6-6 | 162 | 38.3 | 2.8 | 29.2 | 45.6 |
| | E-5 | 159 | 34.5 | 2.3 | 28.4 | 42.0 |
| | D-4 | 157 | 30.6 | 2.1 | 25.2 | 36.9 |
| | C-3 | 148 | 27.6 | 2.1 | 21.1 | 32.4 |
| $T_2 - T_1$ | Posterior Alveolar | 162 | 59.9 | 2.9 | 51.8 | 66.7 |
| | Anterior Alveolar | 162 | 47.2 | 2.4 | 41.3 | 52.8 |
| | 6-6 | 162 | 6.0* | 1.6 | 2.2 | 12.1 |
| | E-5 | 160 | 5.6* | 1.8 | 1.3 | 13.3 |
| | D-4 | 157 | 5.7* | 1.8 | 0.7 | 13.3 |
| | C-3 | 147 | 4.9* | 1.9 | 0.3 | 11.4 |
| | Posterior Alveolar | 162 | 6.2* | 1.7 | 1.2 | 13.0 |
| | Anterior Alveolar | 162 | 5.5* | 1.8 | 1.3 | 12.3 |

* $P < .001$.

ment (T₁) palatal height of 17.6 mm, as measured at the level of the first permanent molars, decreased to 17.0 mm at the time of T₂, a small but statistically significant difference ($P < .001$).

Palatal Depth

A very slight but significant ($P < .05$) decrease in palatal depth was observed between pretreatment (29.5 mm) and postexpansion (29.2 mm) dental casts (Table 2).

Postexpansion Changes in Arch Dimensions

Arch Width

Arch dimensions existing postexpansion (T₂) were given a value of 100%, representing the total arch width present at the time of appliance removal. Arch width measures at later intervals were expressed as percentages of the T₂ (posttreatment) distances.

Maxillary arch widths decreased during the postexpansion period (Figure). For example, at the level of the first permanent molar, 90.5% of transpalatal width was maintained after 1 year, 85.8% after 2 years, and 80.4% at the time of the eruption of the first premolar (T₅). A similar reduction was seen in the premolar and the canine regions.

Table 2. Average Palatal Height and Palatal Depth

| Time | N | Mean (mm) | SD (mm) | Significant to T ₁ |
|----------------|-----|-----------|---------|-------------------------------|
| Palatal height | | | | |
| T ₁ | 162 | 17.6 | 1.7 | na |
| T ₂ | 162 | 17.0 | 2.0 | † |
| T ₃ | 120 | 17.7 | 2.1 | * |
| T ₄ | 90 | 18.3 | 2.1 | † |
| T ₅ | 84 | 18.4 | 2.1 | † |
| Palatal depth | | | | |
| T ₁ | 162 | 29.5 | 2.2 | na |
| T ₂ | 162 | 29.2 | 2.3 | * |
| T ₃ | 119 | 29.4 | 2.2 | ns |
| T ₄ | 88 | 29.6 | 2.2 | ns |
| T ₅ | 81 | 29.4 | 2.2 | ns |

* $P < .05$.

† $P < .001$.

Abbreviations: ns, not significant; na, not applicable.

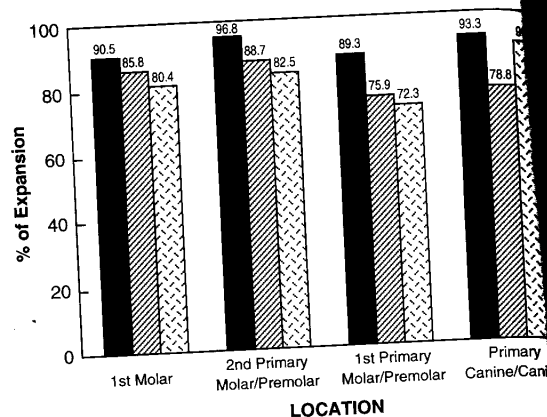


Figure 1. The percentage of original expansion remaining at each posttreatment time period. T₁-1 year post-expansion, T₂-2 years post-expansion, T₅-eruption of upper first pre-molars. ■-T₁, ▨-T₂, ▩-T₅.

Palatal Height

Palatal height, measured from the occlusal plane at the level of the first molars, increased slightly during the postexpansion interval. The mean increase of 0.8 mm measured between the time of T₂ and T₃ indicated that palatal vault height increased to pretreatment value (17.6 mm). Palatal vault height continued to increase, totaling 1.4 mm at T₄ and 1.5 mm at T₅ (Table 2).

Arch Depth

Statistical comparisons of pretreatment and posttreatment measurements of arch depth indicate that palatal depth did not change significantly after treatment (Table 2).

Analysis of Subgroups

Percentage of Expansion Retained versus Initial Arch Width

As mentioned previously, "narrow" and "wide" subgroups were identified, based on the pretreatment arch width of the deciduous first molars. The 20 subjects with the narrow maxillae and the 20 subjects with the wide maxillae were compared. In the analysis of T₅ values, there were significant differences between the groups in the percentage of expansion retained ($P < .05$). For example, the average percentage of expansion retained for the first premolars for the narrow arches was 85.2%, compared with 62.0% for the wide

arches. Similar differences were observed in other arch width measures.

Percent of Expansion Retained versus Initial Tooth Inclination

To determine if initial inclination of the posterior teeth was associated with the amount of stable expansion, the 20 subjects with the most lingually inclined first molars were compared with the 20 subjects with the most facially inclined molars before treatment. Significant between-group differences were observed ($P < .05$); the average percentage of arch expansion retained at the T_5 period was 96.3% and 75.6% for the first molar and first premolar, respectively, for the more lingually inclined group. In contrast, for the arches with initially more facially inclined molars, the average percentage of retained expansion was 83.6% and 66.8% for the first molar and first premolar respectively.

Correlations Between Study Variables and Expansion Retained

To examine the effect of postexpansion time, the percentage of stable first premolar expansion was plotted as a function of time following expansion treatment. The amount of recovery after expansion did not increase as a factor of time ($r = .053$). Width at the deciduous first molar was analyzed to determine its effect on the percentage of first premolar expansion retained at the time of T_5 . Initial arch width was a poor predictor of the stability of expansion ($r = -.168$). When the amount of expansion at the first premolar region was compared to the amount of subsequent relapse, only a weak correlation was found ($r = .468$). In addition, the amount of expansion during treatment indicated essentially no association ($r = .08$) with the amount of stable first premolar expansion.

Further comparisons were made to determine if the stability of the expansion is a function of age, gender, and presence of a pretreatment crossbite. All multiple correlations examined in this study were weak ($r^2 = .01-.21$), suggesting that the changes seen in dental cast dimensions were relatively independent of these variables. Multiple regression analysis failed to show any clinically significant linear combinations of parameters that could be used

to predict future changes in any of the dental cast variables at any time point.

Discussion

This investigation represents the first report from the Ann Arbor Expansion Study, an ongoing clinical trial of the treatment effects produced by rapid maxillary expansion in mixed dentition patients. Records were collected to determine maxillary dental-arch changes occurring after expansion and also during a defined posttreatment interval.

It should be noted that the amount of arch expansion produced by a given RME protocol is variable and is based on the goals of the clinician. For example, Haas⁹⁻¹² recommends opening the expander to the full extent of the screw (10.0 to 10.5 mm), thus maximizing increases in arch width. In the current study, the appliances were expanded more modestly—only to the extent that the lingual surfaces of the upper posterior teeth maintained contact with the buccal cusps of the mandibular teeth. Thus, no buccal crossbite relationships were present at the T_2 time.

Transpalatal Width

Substantial increases in transpalatal width occurred as a result of rapid maxillary expansion. The amount of expansion ranged from 4.9 mm to 6.2 mm, as measured at lingual dental and facial alveolar points (Table 1). The maxillary first molars were present throughout the observation period and, on average, demonstrated about 5 mm of residual expansion at the time of T_5 , 2.4 years after expansion. The net expansion retained at the first molars was 4 to 10 times greater than would be expected without treatment. For example, the average annual change in maxillary arch width from ages 8 to 12 years in untreated individuals is 0.3-0.5 mm at the permanent first molars and -0.5 to 0.3 mm at the deciduous first molars/premolars.^{15,30}

Arch width at the end of the retention period averaged 72% to 91% of the treatment expansion (Fig 1), a 9% to 28% relapse/rebound during the posttreatment period. The amount of rebound reported in this study is considerably less than that reported by pre-

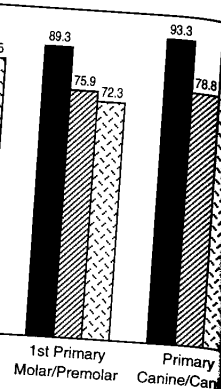


FIGURE 1. Percent of expansion retained at the T_5 period for the first molar and first premolar, respectively, for the more lingually inclined group. In contrast, for the arches with initially more facially inclined molars, the average percentage of retained expansion was 83.6% and 66.8% for the first molar and first premolar respectively.

from the occlusal surfaces of the first molars, increases in arch width during the expansion interval. The amount of expansion measured between T_2 and T_5 indicated that palatal expansion during the pretreatment interval and eight continued to increase at T_4 and 1.5 mm.

pretreatment and posttreatment values of arch depth in the upper arch did not change significantly (Table 2).

Expansion Retained versus Initial Arch Width

"narrow" and "wide" arches were defined based on the percentage of expansion retained at the deciduous first molars. The narrowest arches were those with the widest initial arch width. The analysis of the relationship between the percentage of expansion retained at the first molar and the initial arch width for the wide

vious investigators. Stockfisch⁵⁰ noted 40% to 50% of patients relapse in intermolar width, whereas Linder-Aronson and Lindgren³⁹ reported patient relapse of 55% of the original expansion. Wertz¹³ reported a 30% decrease in intermolar width, as compared to 20% for the present investigation. Stable arch width in the deciduous canines/canine region was 91% of the original expansion in the current study, a relapse of 9%. This amount of relapse was considerably less than the 77% relapse reported by Linder-Aronson and Lindgren³⁹ for the same region.

Although on average a loss of arch width postexpansion was noted, many subjects experienced increases in arch width beyond initial expansion values. These changes occurred in 25% to 30% of the sample and may be related to increases in transpalatal width that occur during normal growth.^{15,30} Wertz¹³ observed increases in skeletal and dental widths following treatment, but only in the younger subjects of his study.

The effects of age and maturation on rapid maxillary expansion, as shown in the cephalometric studies of Krebs^{51,52} and Wertz and Dreskin,¹³ may help explain the differences in results between the present study of mixed dentition patients and previous studies. These investigators showed similar dental width increases during treatment for all age groups, but significant skeletal changes only in younger individuals. Krebs⁵² concluded that, although skeletal expansion is influenced by age, dental expansion is less dependent. In the present study, the average age of the subjects (8.6 years) was significantly younger than the average age (13.5 years) of the subjects used by Timms.³⁵ Subjects from the older age groups may have influenced the average buccal tipping reported by Timms. The flexible appliance design used by Timms in his treatment undoubtedly contributed to the buccal tipping as well.

The appliance used in the present study was rigid in design and remained bonded to the posterior teeth for 5 to 6 months before appliance removal (T_2). The expansion observed did not involve a buccal tipping of the anchor teeth, as has been reported by others. The facial alveolar measures increased to a similar extent, and so did the lingual dental measures

(Table 1), suggesting a bodily movement of the anchor teeth. This observation was verified in a subsequent study of some of the same patients used in this sample. Brust⁵³ and Brust and McNamara⁵⁴ used a digital imaging system developed after the completion of the present study and noted that the average amount of tipping produced by the acrylic splint expander is about one degree, thereby indicating that the movement of the teeth anchoring the acrylic splint expander is bodily in nature.

Subjects with initially narrower maxillae tended to retain more expansion than initial wider maxillae, as measured after the first premolars erupted. Narrow maxillary arches retained 85% of the original expansion, and wider arches retained only 62% of the original expansion. Spillane and McNamara⁵⁵ showed that, in untreated subjects examined annually from ages 7 to 15 years, individuals with initially narrow maxillae experienced greater gains in arch width than did subjects with initially wider maxillae. This observation may corroborate, in part, the differences in residual expansion between the "narrow" and "wide" subgroups.

Palatal Height

During treatment in this study, palatal height decreased slightly as a result of rapid maxillary expansion. As described by Björk and Skieller,⁵⁶ palatal height increases both by vertical development of the maxilla and by alveolar growth associated with the eruption of teeth. The average decrease of 1.7 mm in palatal height observed in this study is contrasted with normal annual increases in palatal vault height of 0.5 mm to 1.0 mm that occurs after the eruption of the maxillary first molar and continues to increase through adolescence.¹⁵ The slight decrease in palatal height observed in the present study may be due to a lateral rotation of the two palatal segments around the mid-palatal suture,^{31,52} thereby causing the palatal vault to become more shallow.

Palatal height increased with time following removal of the expansion appliance. One year after treatment (T_3), palatal height returned to pretreatment values, and two years following expansion (T_4) palatal height averaged 0.5 mm

arches. Similar differences were observed in other arch width measures.

Percent of Expansion Retained versus Initial Tooth Inclination

To determine if initial inclination of the posterior teeth was associated with the amount of stable expansion, the 20 subjects with the most lingually inclined first molars were compared with the 20 subjects with the most facially inclined molars before treatment. Significant between-group differences were observed ($P < .05$); the average percentage of arch expansion retained at the T_5 period was 96.3% and 75.6% for the first molar and first premolar, respectively, for the more lingually inclined group. In contrast, for the arches with initially more facially inclined molars, the average percentage of retained expansion was 83.6% and 66.8% for the first molar and first premolar respectively.

Correlations Between Study Variables and Expansion Retained

To examine the effect of postexpansion time, the percentage of stable first premolar expansion was plotted as a function of time following expansion treatment. The amount of recovery after expansion did not increase as a factor of time ($r = .053$). Width at the deciduous first molar was analyzed to determine its effect on the percentage of first premolar expansion retained at the time of T_5 . Initial arch width was a poor predictor of the stability of expansion ($r = -.168$). When the amount of expansion at the first premolar region was compared to the amount of subsequent relapse, only a weak correlation was found ($r = .468$). In addition, the amount of expansion during treatment indicated essentially no association ($r = .08$) with the amount of stable first premolar expansion.

Further comparisons were made to determine if the stability of the expansion is a function of age, gender, and presence of a pretreatment crossbite. All multiple correlations examined in this study were weak ($r^2 = .01-.21$), suggesting that the changes seen in dental cast dimensions were relatively independent of these variables. Multiple regression analysis failed to show any clinically significant linear combinations of parameters that could be used

to predict future changes in any of the dental cast variables at any time point.

Discussion

This investigation represents the first report from the Ann Arbor Expansion Study, an ongoing clinical trial of the treatment effects produced by rapid maxillary expansion in mixed dentition patients. Records were collected to determine maxillary dental-arch changes occurring after expansion and also during a defined posttreatment interval.

It should be noted that the amount of arch expansion produced by a given RME protocol is variable and is based on the goals of the clinician. For example, Haas⁹⁻¹² recommends opening the expander to the full extent of the screw (10.0 to 10.5 mm), thus maximizing increases in arch width. In the current study, the appliances were expanded more modestly—only to the extent that the lingual surfaces of the upper posterior teeth maintained contact with the buccal cusps of the mandibular teeth. Thus, no buccal crossbite relationships were present at the T_2 time.

Transpalatal Width

Substantial increases in transpalatal width occurred as a result of rapid maxillary expansion. The amount of expansion ranged from 4.9 mm to 6.2 mm, as measured at lingual dental and facial alveolar points (Table 1). The maxillary first molars were present throughout the observation period and, on average, demonstrated about 5 mm of residual expansion at the time of T_5 , 2.4 years after expansion. The net expansion retained at the first molars was 4 to 10 times greater than would be expected without treatment. For example, the average annual change in maxillary arch width from ages 8 to 12 years in untreated individuals is 0.3-0.5 mm at the permanent first molars and -0.5 to 0.3 mm at the deciduous first molars/premolars.^{15,30}

Arch width at the end of the retention period averaged 72% to 91% of the treatment expansion (Fig 1), a 9% to 28% relapse/rebound during the posttreatment period. The amount of rebound reported in this study is considerably less than that reported by pre-

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