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# **Review** Article

# Long-Term Dental Arch Changes After Rapid Maxillary Expansion Treatment: A Systematic Review

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Abstract: This systematic review evaluates long-term dental arch changes after rapid maxillary expansion treatment on orthodontic patients with constricted arches. Clinical trials that assessed dental arch changes through measurements on dental casts or cephalometric radiographs were selected. No patients with surgical or other simultaneous treatment during the active expansion period were accepted. Electronic databases were searched with the help of a senior Health Sciences librarian. Original articles were retrieved from the selected abstracts, and their references were also scanned for possible missing articles. Forty-one articles met the initial inclusion criteria, but 35 were later rejected because they lacked a control group or only evaluated dental changes or used a semirapid technique. Some of them also lacked a reported measurement error. From the remaining articles, two did not report a long-term evaluation. From the final four articles, two measured changes through dental casts and two assessed changes through radiographs (one through lateral cephalometric radiographs and one through posteroanterior radiographs). Similar maxillary molar and cuspid expansion could be found in adolescents and young adults. Significantly less indirect mandibular molar and cuspid expansion was attained in young adults compared with adolescents. A significant overall gain in the maxillary and mandibular arch perimeter was found in adolescents. More transverse dental arch changes were found after puberty as compared with before, but the difference may not be clinically significant. No anteroposterior dental changes were found on lateral cephalometric radiographs. (Angle Orthod 2005;75:155-161.)

Key Words: Rapid maxillary expansion; Dental arch; Long-term effects; Treatment outcome

#### INTRODUCTION

A number of early treatment alternatives for posterior crossbites have been used,<sup>1-3</sup> and rapid maxillary expansion (RME) has been one of the most widely used. It has been used not only to correct maxillary constriction but also to create additional space in the dental arches to relieve crowding.<sup>4.5</sup> Comparisons between the RME treatment outcome reports have been difficult because clinical studies

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vary widely regarding sample size, age range, amount of expansion achieved, and retention methods used.<sup>5</sup>

Contradictory reports and evidence can be difficult to interpret and compare because it is time consuming to read and analyze every article. For this reason, systematic reviews and metanalysis are useful tools to obtain evidencebased clinical information.<sup>6</sup> A systematic review<sup>3</sup> and two metanalyses<sup>4,7</sup> have previously concluded that dental arch changes after RME in clinical trials were inconclusive. Dental arch changes of varying proportions, including reports from complete stability to reports of considerable relapse after maxillary arch expansion were found.

Although the possibility of upper arch expansion with an RME appliance is not questioned, the amount of long-term expansion remaining is very important for borderline extraction cases.<sup>5</sup> Contradictory reports<sup>8–12</sup> of RME long-term stability have been published, all of them without considering normal dental arch changes.<sup>5</sup> Furthermore, previous systematic reviews have not considered publications from all languages.

This systematic review evaluates long-term dental arch changes after RME on patients with constricted arches from all the available literature.

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Database	Database Key Words		Selected	Total Selected Abstracts (%) (41)
Medline	<ol> <li>Rapid maxil\$ expan\$.mp; (2) rapid palat\$ expan\$.mp; (3) exp Tooth/or dental changes.mp; (4) 1 OR 2; (5) 3 AND 4</li> </ol>	62	20	48.8
PubMed	<ol> <li>Rapid maxillary expansion; (2) rapid palatal expansion; (3) dental changes; (4) #1 OR #2; (5) #3 AND #4</li> </ol>	49	19	46.3
Medline in process	<ol> <li>Rapid maxil\$ expan\$.mp; (2) rapid palat\$ expan\$.mp; (3) exp Tooth/or dental changes.mp; (4) 1 OR 2; (5) 3 AND 4</li> </ol>	0	0	0
Embase	(1) Rapid maxil\$ expan\$.mp; (2) rapid palat\$ expan\$.mp; (3) exp Tooth/or dental changes.mp; (4) 1 OR 2; (5) 3 AND 4		0	0
All EBM reviews (Cochrane Data- base of System- atic Reviews, ASP Journal Club, DARE, and CCTR)	<ul> <li>(1) Rapid maxil\$ expan\$.mp; (2) rapid palat\$ expan\$.mp; (3) exp Tooth/or dental changes.mp; (4) 1 OR 2; (5) 3 AND 4</li> </ul>	6	1	2.4
Web of Sciences	(TS = rapid palatal expansion OR TS = rapid maxillary expansion) AND TS = dental changes	11	5	12.2
Lilacs Reference lists	(1) Rapid maxillary expansion; (2) Rapid palatal expansion; (3) #1 OR #2	34 NA	8 6	19.5 14.6

TABLE 1. Sensitivity of Electronic Databases Searched

<sup>a</sup> NA, not applicable.

## MATERIALS AND METHODS

The following inclusion criteria were chosen to select the appropriate articles: RME controlled clinical trials; dental arch measurements made from cephalometric radiographs or dental casts; and no surgical treatment that could affect RME effects during the evaluation period.

A computerized search was conducted using Medline (from 1966 to week five of March 2004), Medline in process (April 9, 2004), Lilacs (from 1982 to March 2004), PubMed (1966 to week five of March 2004), Embase (from 1988 to week 15 of 2004), Web of Science (from 1975 to week five of March 2004), and all EBM Cochrane Research Systems (to the first quarter of 2004) databases for dental arch changes in RME. Terms used in this literature search were rapid palatal expansion or RME and tooth or dental changes. The selection of the specific terms for each database was made with the help of a senior librarian specialized in Health Sciences databases (Table 1).

Eligibility of the selected studies was determined by reading the abstracts of the articles identified by each database. All the articles that appeared to meet the inclusion criteria were selected and collected. The selection process was made by two researchers (Dr Lagravere and Dr Flores-Mir) independently, and then the results were compared. If discrepancies were found, the three researchers (Dr Lagravere, Dr Major, and Dr Flores-Mir) made a final decision together. Articles in which the abstract did not present enough relevant information for its inclusion were also obtained before making a final decision. The reference lists of the selected articles were also searched manually for additional relevant publications that may have been missed in the database searches. The complete manuscripts for the selected articles were independently evaluated by the three researchers (Dr Lagravere, Dr Major, and Dr Flores-Mir). A consensus was reached regarding which articles fulfilled the inclusion criteria, and these were finally included in the systematic review. In cases where relevant data were necessary, the authors, if available, were contacted to obtain the required extra information.

#### RESULTS

From the total abstracts identified in the electronic databases only a relatively small percentage fulfilled the inclusion criteria, as can be seen in Table 1. Comparing the results between databases, Medline obtained the greatest diversity of abstracts but did not include the entire set of abstracts selected in other databases. Lilacs found eight references that were not found in Medline. In the case of PubMed, only 57.9% of the selected references were included in Medline and none from Lilacs.

After collecting all the abstracts from the different databases that appeared to fulfill the selection criteria and verifying their eligibility by reading the actual articles, only 41 studies remained. Because of specific methodological issues, 35 articles were later rejected. All rejected studies lacked a control group to factor out normal dental changes in their analysis,<sup>10,13–43</sup> and some of them also lack measurement error statement.\* The study of Spillane and Mc-Namara<sup>12</sup> was rejected because a control group was only referred to in the discussion and not as part of the statistical analysis. Chang et al<sup>44</sup> only evaluated skeletal changes, and

<sup>\*</sup> References 10, 13-16, 19, 21-23, 25-27, 34-37, 39, 40, 43.

Authors	Sample	Control	Error Method	Evaluation
McNamara et al⁵	61 female and 51 male; 12 y 2 mo $\pm$ 1 y 4 mo	24 male and 17 female	Measures 0.002– 0.06 mm; molar angulations 0.3°	Model casts
Handelman et al46	47 adults (19 male and 28 female; 29.9 $\pm$ 8.0 y) and 47 children (18 male and 29 female; 9.5 $\pm$ 1.3 y)	21 male and 31 female; 32.7 $\pm$ 7.4 y	Assessed but not reported	Model casts
Baccetti et al⁴ <sup>7</sup>	25 female and 17 male (grouped according to skeletal age)	9 female and 11 male (grouped according to skele- tal age)	0.7, SD 0.3 mm	Posteroanterior Cephalometrics
Garib et al⁵⁰	11 male and 14 female (13.6 y; 11– 17.4 y)	13 male and 13 female (paired according to age with treat- ment group)	<0.5°, <0.5 mm	Lateral Cephalo- metrics

TABLE 2. Descriptive Statistics of Treated and Control Groups, Measurement Error, and Evaluation Method Used in the Studies Finally Included

these were not considered. The study of Iseri and Ozsoy<sup>45</sup> was rejected because they used a semirapid maxillary expansion approach.

Finally, only six articles<sup>5,46–50</sup> remained. The Cozza et al<sup>48</sup> and Cross and McDonald<sup>49</sup> studies were excluded because they did not present long-term evaluations. A summary of sample size, retention period, radiographs, and appliances used is presented in Table 2. From the four articles, two measured changes through dental casts and two assessed changes through radiographs (one with posteroanterior radiographs and the other with lateral radiographs).

#### Dental cast assessment in adults

Handelman et al<sup>46</sup> studied retrospectively the long-term efficacy of RME with a Haas-type expander followed by edgewise appliance therapy and determined the incidence of relapse of the dental expansion, tipping of the molars, and gingival recession. All subjects had pretreatment and posttreatment dental casts. No control group for the juvenile sample was used; therefore, only data from the adult sample were used for this review. Expansion screws were activated once daily until the palatal cusps were almost in buccal crossbite. The expander was removed after 12 weeks (range 8-24 weeks). Long-term evaluation for 21 subjects was about five years (minimum one year) after discontinuation of the maxillary retention. A maxillary removable retainer was used after active treatment, and no indication about the lower arch retention was stated. From the long-term records, they found a net gain of 4.8-mm maxillary and 0.7mm mandibular molar transarch width when compared with the control group. For the maxillary first premolar, 4.7-mm transarch width was gained. The maxillary canine transarch width increased 2.3 mm, and the mandibular canine transarch width increased 0.8 mm. All these measurements were taken at the lingual cervical margin.

#### Dental cast assessment in adolescents

McNamara et al<sup>5</sup> evaluated long-term changes in the dental arch dimensions in adolescent patients treated with RME. The Haas-type appliance was activated until 10.5 mm of expansion was attained. The RME appliance was maintained as a passive retainer for a mean of 65 days (range 42–75 days) followed by fixed edgewise appliance treatment. A fixed lower retainer was used after active treatment for the duration of the treatment period. Personal communication with the authors revealed that a maxillary removable retainer was worn full time for one year and at nights for variable time intervals after completion of the use of edgewise appliances. All subjects had pretreatment and posttreatment dental casts. The control group records were obtained from the University of Michigan Elementary and Secondary School Growth Study.<sup>51</sup> Long-term evaluation for the 112 subjects was 6.1 years (SD 1.2) after the completion of treatment.

Compared with the control group, 6.0-mm maxillary and 4.5-mm mandibular arch perimeter gain were achieved in the long term. For the maxillary molar, the first premolar, and the canine, 4.0-, 4.2-, and 2.5-mm arch widths were gained. For the mandibular molar and the canine, 2.5- and 1.5-mm arch widths were gained. These measurements were made between the centroids of each antimere. When measurements were made in the junction of the lingual groove with the palatal mucosa, there was a maxillary molar width gain of 3.7 mm, maxillary first premolar width of 3.7 mm, and a maxillary intercanine width of 2.2 mm. For the mandibular teeth, the intermolar width gained was 5.4 mm and intercanine width was 1.8 mm.

# Cephalometric radiographs assessment (frontal view)

In a retrospective study, Baccetti et al<sup>47</sup> evaluated the dental changes obtained before and after peak pubertal growth spurt using a Haas appliance. The Haas appliance was activated up to 10.5 mm and kept as a retainer for 65 days (range 42–75 days) after active expansion. Three posteroanterior radiographs were taken (initial treatment, immediate postextraction of appliance, and posttreatment of minimum five years). Long-term evaluation of the 42 sub-

jects was about eight years (minimum five years). No indication of the retention protocol was provided. They divided the RME subjects into two groups based on their level of skeletal maturity. The early-maturation group had a mean age of 11 years at baseline and was classified as prepubertal growth spurt. The late-maturation group had a mean age of 13 years and was denominated as peak pubertal growth spurt. The control group was taken from the Michigan Growth Study.<sup>52</sup>

They reported that the early-maturing group presented significantly greater maxillary intermolar width, measured from the most prominent lateral point on the buccal surface of the maxillary first molar (Um-Um +2.7 mm), when compared with the control group. Mandibular intermolar width change was not significant. The late-maturing group also presented significantly greater maxillary intermolar width (Um-Um +3.5 mm) and mandibular first intermolar widths (Lm-Lm +2.3 mm) when compared with the control group. No statistically significant changes were found between any of the groups for the maxillary incisor apex or mesial widths and the maxillary incisal angle. The study authors concluded that a patient treated with Haas expander produces a reproducible amount of expansion at the dentoalveolar level at any development stage.

## Cephalometric radiographs assessment (lateral view)

Garib et al,<sup>50</sup> also in a retrospective study, evaluated long-term effects in dental arches with RME through lateral cephalometric radiographs. The treatment group used a Haas-type expander followed by fixed edgewise treatment. Three lateral radiographs were taken (initial treatment, immediate full-fixed posttreatment, and postretention of a minimum of three years). An upper Hawley retainer for a year and a lower bonded lingual canine-to-canine retainer were placed throughout the evaluated period after the active orthodontic treatment. When compared with the control group, they found a net overjet decrease of 0.6 mm. No statistically significant changes were found concerning molar extrusion, incisor inclination relative to the maxilla and mandible, and overbite. They concluded that the RME treatment did not have significant effects in molar vertical position or in incisor inclination.

# DISCUSSION

It is assumed that less significant results<sup>6,53</sup> and methodological quality are reported in non-English literature.<sup>53</sup> Several systematic reviews in orthodontics do not include non-English databases in their searches. In this review, this could have meant that Garib et al<sup>50</sup> would have not been considered. In this case, one trial (25%) could have important effects on the final conclusions as has been previously stated for metanalysis or systematic reviews with less than five trials.<sup>54,55</sup> Even if only English language databases would have been considered in this systematic review, a literature search in Medline and PubMed will not cover all the available studies because four articles did not appear in any of the databases. Abstracts selected from Web of Science and Cochrane Database of systematic reviews were all included in Medline, although this might not be always true.

The long-term evaluation based on dental casts was made between five and six years after discontinuation of retention. The cephalometric measurements were made after three or five years after finishing active orthodontic treatment without statements of retention protocols. Therefore, caution should be exercised in the interpretation of the long-term effects according to cephalometric analysis. An attempt to contact the authors to clarify the missing information was made without response. Cephalometric measurements regarding intermolar width change are subject to magnification effect and without knowledge of the magnification factor cannot be compared directly with model measurements.

Once the final selection of the articles was obtained, it could be clearly seen that many articles that involved RME treatments have been published. Nevertheless, only four articles satisfied the criteria used in this systematic review, and all have been published no earlier than 2000.

Handelman et al<sup>46</sup> and McNamara et al<sup>5</sup> found very similar increments concerning the maxillary molar and cuspid arch width gains (between 4.8 and 3.7 mm for the molars and first premolars and between 2.3 and 2.2 mm for the cuspids). For the mandibular arch widths, much less expansion was found for the study of Handelman et al<sup>46</sup> compared with that of McNamara et al<sup>5</sup> (0.7 against 5.4 mm for the molars and 0.8 against 1.8 mm for the cuspids). A possible explanation is that the sample of Handelman et al<sup>46</sup> was adult patients, whereas the sample of McNamara et al<sup>5</sup> was adolescents. Moussa et al<sup>24</sup> in an adult sample also found a similar amount of expansion as Handelman et al<sup>46</sup> and concluded that the lower intermolar and intercuspid widths presented a greater relapse tendency because structures are less adaptable in adult patients.

Significant differences in the lower molar arch width were found in the study of McNamara et al<sup>5</sup> in measurements between centroids (2.5 mm) and lingual grooves (5.4 mm). A possible explanation is that RME appliances exert forces on the crowns of the anchorage teeth away from their center of resistance; therefore, lingual tipping of the molar produced a secondary effect that could explain the differential expansion measured. McNamara et al<sup>5</sup> reported 5° of long-term lingual tipping of the mandibular molars and almost 6° of maxillary molar tipping.<sup>26</sup> Handelman et al<sup>46</sup> also reported maxillary molar buccal tipping of 5.1°. However, their report of tipping was after RME retention but before active orthodontic treatment.

McNamara et al<sup>5</sup> reported a significant overall long-term gain in the maxillary (6 mm) and mandibular (4.5 mm) arch

perimeter. This gain could not be attributed exclusively to the RME procedure. Orthodontic treatment after the RME could have played a significant role in this regard. The clinical significance of long-term residual arch width and perimeter gains after RME becomes more obvious if the natural loss during the same period is considered.<sup>5</sup> Without orthodontic intervention, there is a natural dental arch width and arch perimeter loss from late adolescence to their fifth to sixth decade of life.<sup>56</sup> No differences in mandibular measurements were reported regarding the length of the fixed mandibular retention.<sup>5</sup>

Baccetti et al<sup>47</sup> assessed the dental changes through posteroanterior radiographs. When comparing the early- and late-treated groups with their respective controls, there was a significant gain of the maxillary intermolar width (2.7 and 3.5 mm, respectively) in both treated groups. However, in the early-treated group these changes were attributed to the significant expansion of the skeletal maxilla (3.0 mm) against the control group (0.9 mm). They concluded that dental changes after RME are more of a skeletal nature before pubertal peak and more dentoalveolar after pubertal peak.<sup>57,58</sup>

Garib et al<sup>50</sup> assessed dental changes with the use of lateral cephalometric radiographs. When comparing the results before and after treatment, they found no statistically or clinically significant differences in the molar or incisor positions. These results agreed with Cozza et al<sup>48</sup> short-term results on dental changes that were also evaluated through lateral cephalometric radiographs.

Three studies<sup>12,24,45</sup> that were excluded for different reasons should be discussed. Two of them<sup>12,24</sup> reported longterm remaining expansion after RME, whereas one<sup>45</sup> reported long-term changes using a semirapid expansion approach. Spillane and McNamara,12 using acrylic-bonded expansors, reported an average 5-mm residual expansion 2.4 years after expansion. This represented four to 10 times more expansion than that observed in the average maxillary molar arch width change in nontreated individuals from eight to 12 years of age obtained from longitudinal records.<sup>51,59</sup> This study was excluded because no comparison control sample was directly used in the statistical calculations. The theoretical control group was only used in the discussion. Although Moussa et al<sup>24</sup> reported results from 55 patients eight years after retention, they did not use a control sample to factor out normal growth changes. They compared 5.5 mm (upper intermolar width), 2.7 mm (upper intercanine width), 2.4 mm (lower intermolar width), and 0.7 mm (lower intercanine width) of long-term expansion only against previous reports. Iseri and Oszay45 were the first to report the use of a combined RME and slow maxillary expansion (SME) technique. Because the objective of this systematic review was to evaluate long-term dental effects of RME, this study was rejected because it was impossible to differentiate the changes produced by the RME or SME components. Their initial results were promising,

and this technique should be considered as an interesting alternative for constricted maxillary arches.

Future studies regarding long-term dental arch changes with RME should include a clear statement regarding the retention protocol after completion of use of edgewise appliances. Relapse of expansion will very likely be influenced by the length of retention. Fixed lower retention would prevent loss of mandibular cuspid expansion, and it appears that many cases were still being managed with fixed lower retention at the long-term follow-up assessment. Whether removal of the fixed lower retainer would result in loss of expansion is unknown.

A literature review<sup>3</sup> and two metanalysis<sup>4,7</sup> have been published on short-term dental changes in RME. However, clinical trial results for short-term dental arch changes after RME were inconclusive. A significant difference between previous systematic reviews and this review showed that previous reviews included studies that did not present a control group. Although the effect of normal growth during the active phase of expansion (around 30 days) is insignificant,47 it should be considered for the retention period (between two and four months) or, as in this case, during the full period of fixed appliances treatment and the follow-up period. It is of great importance to include a nontreated control group when analyzing long-term changes after RME treatments to factor out normal dental arch changes during craniofacial growth. The magnitude of dimensional change associated with orthodontic interventions can be small; therefore, a statement of measurement errors is required to analyze the real clinical significance of reported changes.

#### CONCLUSIONS

The following long-term dental arch changes were found.

- Based on direct model measurement, clinically significant long-term maxillary molar width increase (3.7–4.8 mm) can be achieved. Because of crown tipping, the amount of reported long-term width increase varied with the reference point used for measurements. The range of maxillary cuspid arch width expansion was more consistent and similar for adolescents and adults (2.2–2.5 mm). Less mandibular molar and cuspid arch width expansion was attained in adults compared with adolescents.
- A significant overall gain was found in the maxillary (six mm) and mandibular (4.5 mm) arch perimeter in adolescents treated with RME and edgewise appliances.
- More transverse dental arch changes were found after puberty compared with before puberty. The difference may not be clinical significant (0.8 mm).
- No anteroposterior or vertical dental changes were associated with RME.

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Angle Orthodontist, Vol 75, No 2, 2005

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161