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# Effect of rapid maxillary expansion on skeletal, dental, and nasal structures: a postero-anterior cephalometric study

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SUMMARY The purpose of this study was to compare the transverse dimensions of skeletal, dental, and nasal structures of a group of patients with maxillary narrowness before and after rapid maxillary expansion (RME) with an untreated control group using postero-anterior (PA) cephalometric radiographs. The material consisted of PA cephalograms of 25 children with a posterior crossbite (mean age 13 years 4 months), and 25 age- and sex-matched controls (mean age 13 years 11 months). Both groups consisted of 20 females and five males. Thirty-four reference points were digitized using the Dentofacial Planner® software program. The 17 variables studied consisted of six skeletal, four dental, and seven intra-nasal linear measurements. Student's *t*-tests were used to compare the differences between the groups, and the effect of RME on skeletal, dental, and nasal structures.

RME produced small, but statistically significant changes in maxillary width, upper and lower molar widths, the width between upper central incisor apices, and intra-nasal width. When compared with previous studies, the changes observed were similar for patients of a similar age group, but less than reported for a younger population. There is some evidence that the pattern of expansion produced by RME will vary depending on the age and maturity of the subject.

## Introduction

The effect of rapid maxillary expansion (RME) on skeletal, dental, and nasal structures was studied extensively in the 1960s and 1970s (Krebs, 1959, 1964; Haas, 1961, 1965, 1970; Wertz, 1970). Recently, there has been renewed interest in the effects of RME when used alone (da Silva *et al.*, 1991, 1995; Ladner and Muhl, 1995; Spillane and McNamara, 1995; Sandikçioğlu and Hazar, 1997; Brosh *et al.*, 1998) and in combination with protraction in the treatment of Class III malocclusions (Baik, 1995; Ngan *et al.*, 1996a,b; Baccetti *et al.*, 1998, 1999). Whereas the sagittal and vertical changes due to RME have been investigated using lateral cephalograms of subjects in the mixed and permanent dentitions (Krebs, 1959, 1964; Haas, 1961, 1965, 1970; Wertz, 1970; da Silva *et al.*, 1991; Akkaya *et al.*, 1999), there have been few studies that have used postero-anterior (PA) cephalograms to assess the transverse changes induced by RME (Haas, 1961; Krebs, 1964; Wertz, 1970; da Silva *et al.*, 1995). This situation may have arisen because researchers have been reluctant to use PA cephalometric radiographs for a variety of reasons such as: difficulties in reproducing head posture and identifying landmarks because of superimposition or poor radiographic technique (Grummonds and Kappeyne van de Coppello, 1987), variable reliability of skeletal and dental PA cephalometric landmarks (El-Mangoury *et al.*, 1987), and difficulty in comparing subjects between centres (Athanasiou *et al.*, 1992). Some of these difficulties may be overcome by careful attention to radiographic technique, and selection of skeletal and dental landmarks that are associated with acceptable reliability. Transverse measurements or widths from PA cephalograms are least affected by positional errors (Ishiguro *et al.*, 1976) and several recent PA cephalometric studies using transverse measurements have been associated with acceptable method error (Athanasiou *et al.*, 1990; Cortella *et al.*, 1997; Sandikçioğlu and Hazar, 1997). Recent publications of normative data for transverse measurements from PA cephalometric radiographs has increased the necessity for a reappraisal of the transverse effects of RME on skeletal, dental, and nasal structures (Athanasiou *et al.*, 1992; Cortella *et al.*, 1997).

The aims of this study were to compare the transverse dimensions of skeletal, dental, and nasal structures in a group of patients with maxillary narrowness before and after RME, with an untreated control group, using PA cephalometric radiographs.

## Subjects and methods

The criteria for selection of the treatment group for the study were as follows: a posterior crossbite with evidence of significant skeletal involvement as judged clinically by an experienced orthodontist, no evidence of adenoidal blockage of the nasopharynx, no previous tonsillar, nasal, or adenoidal surgery. From a total of 72 subjects previously reported (McDonald, 1995), 25 were selected for this study. This group comprised 20 females and five males with an average age of 13 years 4 months (range 11 years 0 months to 15 years 8 months). Twenty-five subjects were sex and age matched from the control population of the previous study (McDonald, 1995). This group had 20 females and five males with an average age of 13 years 11 months (range 10 years 5 months to 15 years 11 months).

All clinical treatment was undertaken by one operator as described by McDonald (1995). Full baseline records included study models, clinical photographs, an orthopantomogram, PA and lateral cephalometric radiographs, and rhinomanometric measurements. The RME appliance used was a cast cap fixed split acrylic appliance with the active expansion produced by a Hyrax screw (11 or 18 mm). The parent activated the appliance 24 hours following cementation and the patients were reviewed on a weekly basis during expansion. During the first week the screw was turned one-quarter three times a day, during the second week this was reduced to one-quarter twice a day and, finally, for the third week the screw was turned one-quarter once a day in the mornings only. If necessary this was continued until the crossbite had been over-corrected so that the palatal cusps of the upper molars were riding up on the buccal cusps of the lowers. When the required expansion was achieved the RME appliance was removed, the screw was locked in position with cold cure acrylic, and the appliance recemented and used as a retainer for 3 months. All baseline records were repeated, and these were used to analyse the skeletal, dental, and nasal effects of RME. The average time between initial and post-expansion radiographs was 3.04 months (SD 1.76). Active expansion using RME took an average 3.75 weeks (range 2.25–5.5 weeks). Fixed appliance treatment was started soon after the retention period.

The subjects were radiographed in the natural head position (NHP) by a single trained radiographer (Solow and Tallgren, 1971). The lateral cephalograms were taken first and then the patient was repositioned in NHP for the PA cephalogram. These radiographs were then traced to show a range of anatomical features using a sharp 4H pencil. The skeletal and dental landmarks chosen for investigation were taken from definitions by Grummonds and Kappeyne van de Coppello (1987), Athanasiou *et al.* (1992) and da Silva *et al.* (1995). Landmarks in the nasal cavity were derived from standard measurements of nasal cavity height and width, and constructed points on the nasal cavity walls. These constructed points were produced using a nasal template for each patient as described below.

A computer-based system was used to digitize radiographs and measure skeletal, dental, and nasal linear measurements. This consisted of a 486 Compaq IBM compatible personal computer and a Numonics 2210–1212 digitizing palette (Numonics, California, USA). The software used was the Dentofacial Planner® version 6.0 (Dentofacial Software, Toronto, Canada). A short six-point digitizing sequence was completed first to allow the construction of a nasal template for each patient (see opposite). The skeletal, dental, and nasal landmarks were then digitized (Figures 1 and 2). From these landmarks a number of measurements were identified and analysed using a customized analysis within the Dentofacial Planner® software program.

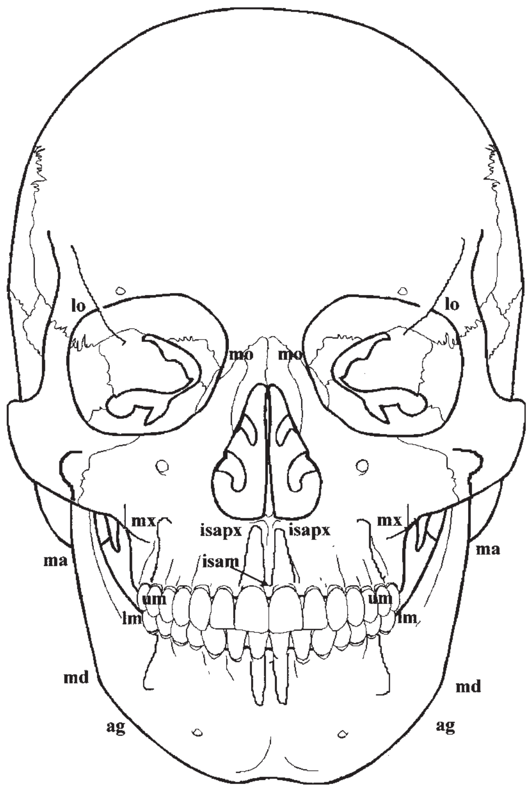


**Figure 1** Skeletal and dental landmarks as identified on a PA cephalometric radiograph. Definition of points are given in Table 1.

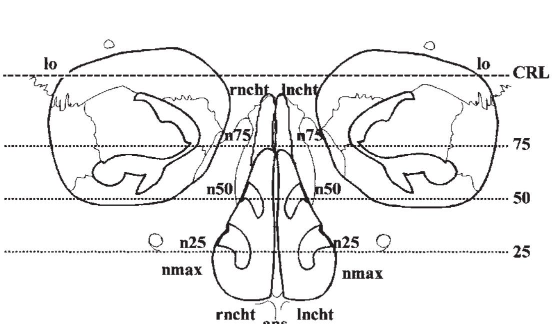


**Figure 2** Nasal cavity landmarks showing the use of the nasal template to identify constructed point on the nasal cavity walls.

*Nasal template*

In an attempt to examine changes in the transverse width of the nasal cavity at different levels, a template was constructed for each patient. This involved digitizing the nasal cavity heights, and skeletal points, right and left lateral orbit (Llo and Rlo). These were then used to calculate the total nasal cavity height and construct a template, which consisted of four parallel lines (Figure 2). The first three lines divided the nasal cavity into four equal sections corresponding to one-quarter, one-half, and three-quarters of the nasal cavity height. These lines were constructed parallel to the fourth or cranial reference line (CRL), i.e. a line drawn between Llo and Rlo (Hicks, 1978; Mossaz *et al.*, 1992). The CRL was then used to locate the template under subsequent tracings by aligning it with the points Llo and Rlo (Figure 2). In this way, individual nasal templates could be placed underneath acetate tracings for each patient to allow easy identification of the constructed points on the lateral and medial nasal cavity walls (Cross and McDonald, 1998).

All skeletal, dental, and nasal linear measurements were subjected to method error analysis using duplicate tracings of the control group (Houston, 1983). A period of at least 4 weeks elapsed between duplicate tracings and comparisons between the two sets of readings were carried out. Systematic error of those variables under study was examined using a Student's *t*-test, and random error was assessed using the modification of Dahlberg's formula suggested by Hald (1960). Index of reliability was calculated as recommended by Houston (1983). The results of the method error analysis indicated there were no systematic differences and that the majority of the measurements were associated with percentage errors of less than 10 per cent. Although the percentage errors were larger than ideal, for the purposes of this study it was decided to retain the following measurements in the analysis: the nasal cavity width at the n50 and n75 lines. Details of the measurements selected

**Table 1** Measurements used in the study including method error for skeletal, dental and nasal measurements from duplicate tracings of control group where appropriate.

| | Measurement | Description | Index of reliability | Random error $s(i)$% | Systematic error ($t$-test) |
|---|---|---|---|---|---|
| 1 | lo–lo | Inter–orbital width | 0.99 | 0.93 | NS |
| 2 | mo–mo | Medial orbital width | 0.99 | 2.43 | NS |
| 3 | ma–ma | Mastoid width | 0.99 | 2.8 | NS |
| 4 | mx–mx | Inter–maxillary width | 0.98 | 3.73 | NS |
| 5 | md–md | Mandibular width | 0.99 | 0.8 | NS |
| 6 | ag–ag | Antegonial width | 0.97 | 6.16 | NS |
| 7 | um–um | Upper inter–molar width | 0.97 | 4.84 | NS |
| 8 | lm–lm | Lower inter–molar width | 0.98 | 3.97 | NS |
| 9 | isapx–isapx | Upper inter–incisal width–apex | 0.98 | 3.87 | NS |
| 10 | isam–isam* | Upper incisor alveolar crest width | – | – | – |
| 11 | rncht | Right nasal cavity height | 0.96 | 7.65 | NS |
| 12 | lncht | Left nasal cavity height | 0.97 | 6.02 | NS |
| 13 | ans* | Anterior nasal spine | – | – | – |
| 14 | nmax–nmax | Maximum nasal cavity width | 0.98 | 3.58 | NS |
| 15 | n25 | Width of nasal cavity at n25 line | 0.97 | 6.36 | NS |
| 16 | n50 | Width of nasal cavity at n50 line | 0.93 | 13.29 | NS |
| 17 | n75 | Width of nasal cavity at n75 line | 0.94 | 12.47 | NS |

$n = 25$, $s(i)$% = percentage method error, NS = not significant, * = measurement not possible before expansion.

for further study are given in Table 1, and Figures 1 and 2.

All measurements conformed to normal distribution and, as such, parametric statistical tests were judged to be suitable for both within group and between group comparisons. Owing to the number of tests, it was decided that the level of significance should be $P < 0.01$. All statistical tests were accomplished using an Excel spreadsheet software package (Microsoft, USA).

## Results

### *Comparison of control and treatment groups before expansion*

The majority of transverse skeletal, dental, and nasal measurements did not differ significantly between groups (Table 2), but upper molar transverse width (um–um) was significantly smaller in the treatment group before expansion. The following measurements tended towards statistical significance: maxillary skeletal width (mx–mx) and the distance between the apices of the upper central incisors (isapx–isapx).

### *Effect of RME on the treatment group*

There was a small, but statistically significant, change in skeletal maxillary width (mx–mx) due to treatment. This was found to increase by 1.11 mm as a result of RME ($P < 0.001$). Separation of the median palatine suture was observed at the level of the anterior nasal spine, with the mean width between the left and right halves of the anterior nasal spine (ans–ans) following expansion found to be 3.19 mm (range 2.1–4.6 mm). Further evidence of separation of the suture was evident at the level of the alveolar process close to the upper central incisors (isam-isam). The width between these points was found to increase by a mean of 3.42 mm (range 1.6–5.2 mm) due to expansion.

Mean upper molar width (um–um) increased significantly with treatment, with a mean expansion of 5.5 mm (range 1.3–13.8 mm, $P < 0.001$). A small increase in lower inter-molar width was found (0.66 mm, $P < 0.01$). The apices of the upper central incisors (isapx–isapx) were carried laterally a mean distance of 3.98 mm (range 0.9–10.5 mm) due to expansion (Table 2).

**Table 2** Comparison of control and treatment groups with results of Student's *t*-tests

| | Parameter | Control (1) | | Before RME (2) | | After RME (3) | | Change due to RME | | *P* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *x* | SD | *x* | SD | *x* | SD | *x* | SD | 1′–2[a] | 2′–3[b] | 1′–3[a] |
| 1 | lo–lo | 90.9 | 4.9 | 90.82 | 3.61 | 91.14 | 3.7 | 0.32 | 1.08 | – | – | – |
| 2 | mo–mo | 24.71 | 2.69 | 23.58 | 2.12 | 24.0 | 2.34 | 0.42 | 0.98 | – | – | – |
| 3 | ma–ma | 113.0 | 5.19 | 111.04 | 4.96 | 111.74 | 5.07 | 0.7 | 1.23 | – | – | – |
| 4 | mx–mx | 62.57 | 3.08 | 59.81 | 4.0 | 60.92 | 3.94 | 1.11 | 1.41 | * | *** | – |
| 5 | md–md | 96.26 | 4.7 | 96.38 | 4.81 | 96.72 | 4.77 | 0.34 | 0.86 | – | – | – |
| 6 | ag–ag | 84.73 | 2.4 | 83.92 | 4.16 | 84.5 | 4.12 | 0.58 | 1.43 | – | – | – |
| 7 | um–um | 56.4 | 2.89 | 51.87 | 3.12 | 57.37 | 3.82 | 5.5 | 2.49 | *** | *** | – |
| 8 | lm–lm | 55.14 | 2.92 | 55.82 | 3.17 | 56.48 | 3.04 | 0.66 | 0.91 | – | ** | – |
| 9 | isapx–isapx | 7.4 | 1.73 | 6.34 | 0.99 | 10.32 | 1.77 | 3.98 | 2.13 | * | *** | – |
| 11 | rncht | 44.29 | 2.56 | 44.94 | 2.35 | 46.06 | 2.21 | 1.11 | 2.01 | – | * | – |
| 12 | lncht | 44.68 | 2.35 | 45.26 | 2.66 | 46.53 | 2.56 | 1.26 | 2.1 | – | * | – |
| 14 | nmax–nmax | 28.14 | 2.3 | 26.84 | 3.87 | 27.9 | 4.28 | 1.06 | 1.13 | – | *** | – |
| 15 | n25 | 25.76 | 2.57 | 25.36 | 2.2 | 25.52 | 2.19 | 0.16 | 1.29 | – | – | – |
| 16 | n50 | 17.64 | 2.24 | 16.4 | 2.12 | 16.42 | 2.25 | 0.1 | 2.19 | – | – | – |
| 17 | n75 | 7.62 | 2.25 | 6.75 | 1.63 | 7.02 | 1.53 | 0.27 | 1.7 | – | – | – |

[a]Two-sample *t*-tests; [b]paired *t*-tests.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

The maximum nasal width of the nasal cavity (nmax–nmax) increased by a mean of 1.06 mm ($P < 0.001$). The height of the nasal cavity was found to increase due to treatment by a mean of 1.11 and 1.26 mm for the right and left sides, respectively. These small increases in nasal cavity height tended towards statistical significance, otherwise intra-nasal changes were small and did not reach statistical significance (Table 2).

### *Comparison of treatment and control groups after expansion*

A comparison of the skeletal, dental, and nasal transverse measurements for the treatment group after RME and the control group revealed that there were no statistically significant differences between groups in either skeletal or dental measurements (Table 2).

### *Comparison with previous studies*

In order to establish the normality of the control group they were compared with standard values and ratios published by Athanasiou *et al*. (1992), who recommended the use of ratios to compare different study populations (Table 3). The ratios given as standards were selected from data published by Athanasiou *et al*. (1992) to closely represent the age range encountered in this study (i.e. 10–15 years). All width ratios given are with reference to lateral orbital width (lo–lo). It may be seen from Table 3 that the majority of ratios for controls in this study matched very closely those published for Northern European norms. Ratios for the treatment group both before and after treatment are also given in Table 3. The pre-treatment inter-maxillary width ratio (mx/lo) was 0.659 for the RME group, compared with 0.689 for the control group and 0.686 for the Northern European sample. This ratio increased to a mean value of 0.668 following expansion, which indicates some improvement, but not complete correction. Upper molar width ratio (um/lo) in the treatment group before RME was 0.571 compared with 0.621 for the control group and 0.61 for the published normal value. After expansion this ratio increased to 0.629, which was greater than for the other groups. The ratio for lower molar width (lm/lo) for both

**Table 3** Comparison of control and anomaly groups using ratios calculated from linear measurements ($n$ = 25, mo = width mo–mo, lo = width lo–lo, etc.). Controls from Athanasiou *et al*. (1992), NR = ratio not reported.

| Ratio | Control group | Athanasiou control group | Treatment group | |
|---|---|---|---|---|
| | | | Before | After |
| mo/lo | 0.271 | 0.271 | 0.260 | 0.263 |
| ma/lo | 1.242 | 1.210 | 1.223 | 1.226 |
| mx/lo | 0.689 | 0.686 | 0.659 | 0.668 |
| md/lo | 1.058 | NR | 1.061 | 1.061 |
| ag/lo | 0.933 | 0.913 | 0.924 | 0.927 |
| nmax/lo | 0.309 | 0.307 | 0.296 | 0.306 |
| um/lo | 0.621 | 0.610 | 0.571 | 0.629 |
| lm/lo | 0.606 | 0.606 | 0.615 | 0.620 |

the control group and published norms is 0.606. This compared to a larger ratio before treatment of 0.615 for the treatment group, which increased to 0.62 after expansion.

Table 4 shows the amount of expansion achieved at various levels expressed as a percentage of the total expansion observed at the alveolar level. Data from da Silva *et al*. (1995) are shown together with changes observed for all RME patients in this study. It may be seen from Table 4 that those authors found only 56 per cent of the expansion achieved at the alveolar level was present at the level of the anterior nasal spine and only 43 per cent at the level of the nasal cavity. In all treatment patients in this study, 94 per cent of the expansion at the alveolar level occurred at the anterior nasal spine, whereas only 32 per cent of this expansion was found at the level of the nasal cavity.

## Discussion

The treatment group contained 20 females and five males which reflects to a degree the difference in sex ratio in the original sample. In a study of the effects of RME, differences between the sexes may prove to be important as it is known that the facial skeleton increases its resistance to expansion significantly with increasing age and maturity (Zimring and Isaacson, 1965; Bell, 1982). As girls complete puberty earlier than boys this may affect resistance to the forces of expansion. Twenty-five subjects were age and sex matched to the treatment group from the control population of the previous study by McDonald (1995). A Student's *t*-test (two-sample) demonstrated that these two groups did not significantly differ with respect to age.

All the skeletal and dental transverse measurements were associated with an acceptable method error. In this study, careful attention to radiographic technique, and the selection of PA cephalograms on the basis of quality and clarity of landmarks resulted in acceptable method error for width measurements. The nasal template was developed to help reduce random measurement error of the nasal width at various levels within the cavity. Despite this, percentage random errors in the width of the nasal cavity at the n50 and n75 levels were higher than ideal (13.29 and 12.47 per cent, respectively). This may

**Table 4** Comparison of the amount of expansion produced by RME in the anomaly group expressed as total mean expansion (mm) and as a percentage of that recorded at the alveolar level (isam–isam). Figures reported by da Silva *et al*. (1995).

| Measurement level | | da Silva ($n$ = 50, $x$ = 8y 0m) | | RME ($n$ = 25, $x$ = 13y 4m) | |
|---|---|---|---|---|---|
| | | mm | % | mm | % |
| Intranasal | nmax–nmax | 2.08 | 43 | 1.06 | 32 |
| Posterior maxilla | mx–mx | 2.81 | 59 | 1.11 | 32 |
| Anterior maxilla | ans | 2.66 | 56 | 3.19 | 94 |
| Alveolar | isam–isam | 4.77 | 100 | 3.42 | 100 |
| Upper molars | um–um | 5.47 | – | 5.5 | – |

reflect the relatively smaller transverse widths involved at these levels and the overall anatomy of the nasal cavity (Table 1, Figure 2).

Differences between the treatment group before RME and the untreated control group were small, and with the exception of upper molar width, these groups were essentially similar. This suggests that the treatment group in this study was composed of a heterogeneous sample with the relative contribution of the skeletal and dentoalveolar components to the posterior crossbite differing between patients. Although no statistically significant differences were found intra-nasally, the mean intra-nasal widths were generally slightly lower for the treatment group. This suggests that severe maxillary skeletal narrowness is required before intra-nasal width is significantly affected.

Maxillary width increased by a mean of 1.11 mm (SD 1.41) as a result of RME, which is modest compared with other studies (da Silva *et al*. 1995). The large standard deviation reflects the variation between individuals in response to RME. This variation may be due to two factors. First, point mx lies at the intersection of the lateral contour of the maxillary alveolar process and the lower contour of the maxillozygomatic process of the maxilla (Athanasiou *et al*., 1992). It has been suggested that the pterygoid plates may provide the greatest resistance to expansion, so it is not surprising that the expansion achieved in this area can be modest in some subjects (Timms, 1980, 1986). Secondly, the median palatine suture closes or ossifies from the posterior aspect first and this may restrict the degree of expansion at this point. It was observed that some patients exhibited very little change in maxillary width, which prompted further investigation into patients who responded to expansion at this level.

The upper molar width increased by a mean of 5.5 mm, although in one patient an increase of 13.8 mm was recorded. As the force of expansion is applied directly to the maxillary teeth it is to be expected that the greatest increase will be found in this area. These changes are similar to those reported elsewhere (da Silva *et al*., 1995; Spillane and McNamara, 1995). However, it should be remembered that the mean age of the patients who had undergone expansion in those investigations was significantly younger than in the present study. Furthermore, clinical criteria were used to determine the end-point of the expansion, i.e. slight over-correction of the cross-bite. These two considerations mean that although the degree of upper first molar expansion may be similar between studies, the pattern of orthopaedic movement and the relative contribution of orthopaedic and orthodontic movements to the observed clinical expansion may differ between studies of different age groups. The creation of a diastema was a consistent feature in this study with the apices of the upper central incisors separated by a mean distance of approximately 10 mm after expansion. Lower molar width increased by a mean of 0.66 mm (SD 0.91) and this finding would appear to support previous findings that uprighting of lower molars can occur (Gryson, 1977; Sandstrom *et al*., 1988). The mechanism for this uprighting appears to be due to either altered muscle balance or to occlusal forces secondary to maxillary expansion or a combination of both (Haas, 1980).

RME produced small intra-nasal changes and the maximum width of the nasal cavity was found to increase by a mean distance of 1.06 mm (Table 2). This is a modest increase compared with recent studies (da Silva *et al*., 1995; Table 4), but is similar to results reported by earlier workers. Using metallic implants in 23 patients, Krebs (1959) demonstrated that, following RME, the mean gain in nasal cavity width was 1.4 mm (range 0.1–2.8 mm). Thorne and Hugo (1960), using occlusal radiographs, reported an average increase in maximum nasal cavity width of 1.7 mm (range 0.4–5.7 mm). Interestingly, there was no difference in width detected at the other levels within the nasal cavity, i.e. n25, n50, and n75, for the treatment group as a whole. It is likely that the expansion achieved intra-nasally in this group of patients was restricted to the lower part of the nasal cavity. It would appear that expansion *in vivo* does not reach the nasofrontal suture, but diminishes rapidly once inside the nasal cavity. It is important to note that in the subjects in this investigation, a moderate increase in upper molar width was associated with a very small mean increase in intra-nasal width. It remains to be seen if this increase has a significant effect on nasal cavity function. An interesting finding in this group of patients was the tendency for a small increase in nasal cavity height following RME. This is thought to be due to an outward rotation of the maxillae during expansion, which lowers the nasal floor (Haas, 1961; Wertz, 1970; da Silva *et al*., 1991, 1995; Spillane and McNamara, 1995). Separation of the anterior aspect of the median palatine suture occurred in all subjects, with the two halves of the anterior nasal spine being a mean of 3.19 mm after RME.

The comparison of the control group with the treatment group after expansion demonstrated that following treatment no significant differences in transverse measurements remained between these groups. This could be interpreted as evidence that the RME had normalized the treatment group. However, there remained differences between these groups as indicated by the ratios given in Table 3. The inter-maxillary width ratio (mx/lo) was found to be 0.659 for the treatment group before treatment compared with 0.689 for the control group and 0.686 for the Northern European norms. This would appear to corroborate the results found above, that the treatment group exhibited a general maxillary narrowness. Following treatment this ratio increased to 0.668, an overall improvement. However, as a result of poor maxillary width increase in some individuals this value was still lower than for either of the control groups. A similar pattern was found in the upper molar ratios (um/lo) with an increase from 0.571 to 0.629 following treatment. The value of the um/lo ratio for the treatment group after expansion was slightly higher than that for either of the control groups and may reflect the slight over-expansion in each case. Athanasiou *et al*. (1992) recommended the use of ratios to compare the results of studies using PA cephalograms from different centres. Ratios were used in this study to demonstrate that the control population closely matched figures produced for Northern European norms for that age group. These ratios were also useful in detecting subtle differences between treatment and control groups that would not have been apparent if data analysis was restricted to common statistical tests.

From the results in Table 4 an attempt was made to consider the overall shape of the expansion produced by RME in different study populations in both transverse and coronal planes. Comparison of the degree of expansion at the alveolar level (isam–isam), anterior nasal spine (ans–ans), and maximum width of the nasal cavity (nmax–nmax) can give an indication of the shape or pattern of skeletal expansion in the transverse plane. Similarly, a comparison of the amount of expansion achieved at the anterior nasal spine (ans–ans) and the maxillary base (mx–mx) can provide information on the pattern of expansion produced in the coronal plane. It is clear from Table 4, that the pattern of expansion produced by da Silva *et al*. (1995) in both the transverse and coronal planes was different from this study population. This variation may reflect the difference in mean age between these two studies, with the older age group having much less expansion intra-nasally (nmax–nmax) and at the posterior aspect of the maxilla (mx–mx), but more expansion at the anterior aspect of the maxilla (ans–ans). Although the appliances used in both investigations were not identical, it may not be unreasonable to assume that the increased maturation of facial structures and sutures in the older patients will help resist the forces of expansion and possibly result in more bone bending. Some of this resistance may be due in part to the partial ossification of the median palatine suture beginning at its posterior aspect (Persson and Thilander, 1977). No feature could be identified that would help predict those subjects most likely to respond to RME either skeletally or intra-nasally. It is likely that patients respond to RME on a highly individual basis. Previous workers have suggested that most of the resistance to RME is due to circummaxillary structures (Isaccson *et al*., 1964: Wertz, 1970; Persson and Thilander, 1977), and it is reasonable to assume that resistance will increase as these structures grow and mature.

In summary, the dental expansion produced by RME in this study was similar to previous reports, but the amount of skeletal expansion was less than that achieved in younger populations. On average, the amount of intra-nasal expansion was small and restricted to the lower half of the nasal cavity. Unfortunately, it would appear impossible to predict, from this group of patients, who will respond to RME skeletally or intra-nasally. In theory, for patients who are less skeletally mature, separation of the maxillae may be easier and result in more parallel expansion. To achieve the maximum skeletal response perhaps patients should be treated younger than in the present study. The disadvantage of this approach is that treatment time is prolonged with two phases of orthodontic treatment separated by a retention phase. Those patients that experience an increase in nasal cavity width due to RME will also have a small increase in nasal cavity height. However, it remains to be seen if these changes will be clinically significant. The influence of RME on the nasal function of the treatment group will be reported in a further paper.

## Conclusions

1. The majority of dental transverse measurements changed significantly as a result of RME. While the expansion across the upper molars was expected, some patients had a small increase in lower molar width. A midline diastema resulted in all subjects at the end of the expansion period.
2. RME resulted in a small, but significant increase in maxillary base width, although there was great individual variation. Separation of the anterior nasal spine, and therefore the anterior part of the median palatine suture, occurred in every case.
3. Intranasal changes as a result of RME were small and width increases were restricted to the lower part of the nasal cavity. There was also a tendency for an increase in nasal cavity height. It remains to be seen if these changes will be clinically significant.
4. RME produced less expansion both skeletally and intra-nasally when compared with a younger population from a previous study. The overall pattern of expansion differed between these two age groups. The reasons for the differing responses probably lie in the maturity of the maxillofacial structures.

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