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## Upper and lower arch changes after Mixed Palatal Expansion protocol

### ABSTRACT

**Aim** The aim of this study was to evaluate upper and lower dental changes after Mixed Palatal Expansion (MPE) treatment in growing patients with posterior single or bilateral crossbite and mild-to-moderate crowding, as compared to untreated growing subjects by dental cast analysis.

**Materials and methods** A group of 24 patients (18 girls, 6 boys) was treated with Hyrax-type device and compared with an untreated matched control group at T0 (8.6 yrs.  $\pm$  2) and at T1 (10 yrs.  $\pm$  2) using dental casts. The dental cast analysis was performed on four dental bilateral landmarks, on upper and lower casts; also upper and lower arch depths were measured. The groups were compared using independent sample t-test to estimate dental changes in upper and lower arches.

**Results** The MPE group showed significant upper and lower arch changes when compared with the control group. Upper intermolar, interpremolar-2nd, interpremolar-1st ( $P < 0.001$ ) and intercanine widths ( $P < 0.05$ ) showed considerable changes in the treated group, while mandibular intermolar ( $P < 0.001$ ), interpremolar-1st ( $P < 0.05$ ) and intercanine widths ( $P < 0.01$ ) were slightly greater in the MPE group when compared with the control group.

**Conclusion** The changes in transverse upper and lower arch dimensions were significant, when compared with those seen in the control group.

**Keywords** Mixed palatal expansion; Posterior crossbite; Transverse dimension.

## Introduction

Maxillary expansion has been used for decades to correct skeletal transverse deficiency associated with posterior uni- or bilateral crossbites [Cross and Mc Donald, 2000; Lagravère et al., 2005; Lagravère et al., 2013; Schiffman and Tuncay, 2001; da Silva Filho et al., 1995; Maspero et al., 2012].

As self-correction is rare, untreated posterior crossbites often worsen [da Silva Filho et al., 1995; Perillo et al., 2011] and limit maxillary growth [Baccetti et al., 2001; Ferro et al., 2003]. Maxillary expansion, indicated in growing patients with primary [Promožic et al., 2013] and mixed [Geran et al., 2006] dentitions, results in an increased transverse maxillary width that allows maxillary and mandibular arch coordination, and sometimes the forward repositioning of the mandible. Moreover, with the increased transverse width, in patients without crossbite but with mild-to-moderate tooth-size/arch-size discrepancy, maxillary expansion may eliminate the need for extractions [Baccetti et al., 2001; Baccetti et al., 2000; Adkins et al., 1990].

Over the years, different protocols of maxillary expansion have been proposed such as the rapid, semi-rapid and slow expansion. To achieve more skeletal changes and minor dental movements, an expansion protocol called Mixed Palatal Expansion (MPE), due to the rapid activation at the first appointment followed by a slow activation at subsequent appointments, has been previously proposed [Grassia et al., 2014]. The MPE is a useful procedure to achieve major skeletal and minor dental changes, because the expansion forces are completely directed on the two maxillary halves, already separated at the first appointment. The previous study [Grassia et al., 2014] showed that in pre-pubertal patients the MPE was effective in improving the dentoskeletal transverse dimensions as derived by postero-anterior cephalograms [Perillo et al., 2014].

Often upper [Moussa et al., 1995; Spillane and McNamara, 1995] and lower [Gryson; 1977; Sandstrom et al., 1988] dental changes resulting from dental cast analysis are also associated with maxillary expansion but no study on MPE and a few studies with other expansion protocols reported these changes, compared with those of an untreated control group [Geran et al., 2006; Krebs, 1964]. The purpose of this study was, therefore, to analyse and compare upper and lower dental changes related to MPE treatment in growing patients with single or bilateral posterior crossbite and/or mild-to-moderate crowding versus those occurring in untreated growing subjects.

## Materials and methods

The expansion group consisted of patients treated at the Department of Orthodontics, Second University of

Naples, Italy, from January 2008 to December 2010.

The following inclusion criteria were used: pre-pubertal age, single or bilateral posterior crossbite and/or mild to moderate-crowding, dental casts and good quality postero-anterior (PA) radiographs at T0, no sooner than four months before the application of the appliance, and at T1, no later than one month after the expansion. Additionally, an occlusal x-ray confirming successful separation of the midpalatal suture was required. Subjects with a history of orthodontic treatment, dental trauma or anomalies, dentofacial abnormalities or syndromes were excluded. Out of 200 subjects, 24 patients matched the criteria and were included in this study. The MPE group consisted of 18 girls and 6 boys with a mean age of 8.6 years  $\pm$  2 at T0 and 10 years  $\pm$  2 at T1. The cervical vertebral maturation stage of these patients ranged from CS1 to CS2 [Sandstrom et al., 1988].

Active therapy lasted approximately 6 months  $\pm$  2 and was followed by a retention period of 1 year  $\pm$  3. All subjects were compared with a sex and age matched normative increments inferred by interpolation from the published standards of occlusal development and derived from the University of Michigan Elementary and Secondary School Growth Study [Moyers et al., 1976] (Table 1).

### Clinical procedure for MPE

A Hyrax-type expander is bonded to the first upper molars and first deciduous molars or first bicuspid allowing three or four activations to be performed, all in the same day. After the first activations with four turns ( $\pm$  0.25 mm per turn), the patient usually has tenderness on the bonded teeth for 20 to 30 minutes. Then, after the second activation with two turns, the tenderness shifts to the palatal incisor area for 10-15 minutes, whereas after the third activation with one turn, tenderness is felt in the suture area for the same amount of time. The decrease in tenderness on the bonded teeth and/or tenderness in the midpalatal suture area may indicate that maxillary halves have already been separated. However, only an occlusal x-ray can confirm a successful separation. In the event of increased palatal suture resistance, a fourth activation with two additional turns may be applied. In this case, there can be tenderness at

Group	Number			Average age (yr/mo)	
	Total	M	F	Start	Finish
MPE group	24	6	18	8.6	10
Michigan control group *	24	6	18	8.6	10

\*Data inferred from from age- and sex-matched Michigan standards (\*)

TABLE 1 Sample description.

the temporal and frontozygomatic areas. Therefore, the number of activations and related turns depends on how much the suture is interdigitated.

After opening the suture, a slow expansion protocol with one turn every three days is followed until 2 mm overcorrection are obtained. The activation period usually lasts from 3 to 6 months depending on the extent of the maxillary expansion. After expansion, the Hyrax device is removed to lock the screw with cold acrylic and then re-cemented, so that it could be used as a retainer during the retention phase.

### Data collection

Digital occlusal photographs were taken of all maxillary and mandibular casts according to a standardised technique and imported into Adobe Photoshop, version 5.0 (Adobe Systems, San Jose, Calif). Each photo was saved with a 5-mm grid box and then imported into Scion Image (Scion, Frederick, MD; a version of the Macintosh program, NIH Image, from the National Institutes of Health); which can be used to capture, display, analyze, enhance, measure, annotate, and output images. Each point in Scion was recorded to an x, y coordinate system and imported into a Microsoft Excel program, to orient the coordinates and align the maxillary and mandibular casts. The dental casts were measured at T0 and T1 for each patient.

### Landmarks identification

Landmarks were identified on the distal, facial, mesial, and lingual surfaces of each tooth from the right first permanent molar to the left first permanent molar in the same arch (Fig. 1). These points were selected in accordance with the guidelines established by Moyers [1976] and Brust and McNamara [1995] to determine the geometric center of each tooth, i.e. the tooth centroid. This point provides a more valid measurement of arch width because it removes the effect of tooth rotation.

Landmarks were not recorded if the teeth were in the process of exfoliation, ectopically erupted, or in the process of eruption if the height of the four outer surfaces (distal, facial, mesial and lingual) was visible.

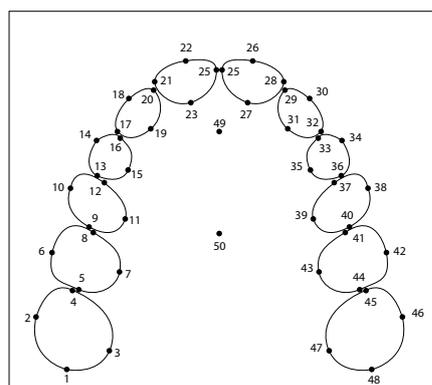
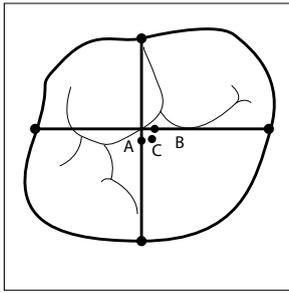


FIG. 1 Location of landmarks on maxillary dental casts. Similar dental landmarks were located on the mandibular dental arch.



**FIG. 2** Location of the centroid of each posterior tooth was determined by selecting the midpoint (A) of a line connecting the mesial and distal landmarks. A similar midpoint (B) was located midway the buccal and lingual landmarks. The centroid (C) was located midway between A and B.

### Measurements

For each dental arch, at T0 and T1, four transversal linear measurements (arch widths), connecting the centroid of a tooth (Fig. 2) and its antimere [Moyers et al., 1976; Brust and McNamara, 1995], and one sagittal measurement (arch depth) were analysed. For each tooth it was determined the midpoint of a line connecting mesial and distal landmarks, and another midpoint was constructed midway between buccal and lingual landmarks of the tooth; the centroid is located midway between the midpoints. In the majority of the teeth studied, the centroid and the midpoint between the proximal midpoints coincided or were very close to each other.

Arch width was measured at the following teeth on both arches: primary/permanent canines, first primary molars/first premolars, second primary molars/second premolars, and first permanent molars. Arch depth was determined by measuring length of perpendicular line constructed from contact point between mesial contact points of central incisors to line connecting points between second premolars and first molars (Fig. 3).

### Error method

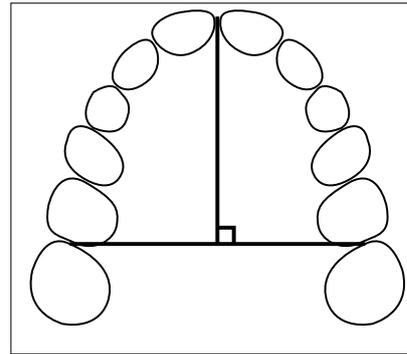
The error standard deviation was calculated from the double determinations of twelve randomly selected dental casts, re-measured after an interval of 1 week, with the aid of the Dahlberg's formula. The mean value of the method error was  $0.5 \text{ mm} \pm 0.2 \text{ mm}$ .

### Statistical analysis

Changes in both groups, together with the differences between the groups, were evaluated by Student's t-tests. Individual changes were recorded as change per year to express variation in intervals between films and thereby allowing a comparison with the control group data. Data were analysed with the Statistical Analysis System (SAS version 9.2, SAS Inc. Cary, NC). The level of significance was set at  $p < 0.05$  for all statistical analyses.

## Results

The method error ranged between 0.5 mm and 0.2 mm for the linear measurements, indicating that there was a good reliability of measurements.



**FIG. 3** Arch depth was measured as the distance from a point midway between the facial surfaces of the central incisors to a line tangent to the mesial surfaces of the first permanent molars.

### Comparison of starting forms

At T0 all width and depth measurements for maxillary starting arch form were significantly smaller in the MPE when compared with the control group (CG), whereas no significant differences in all mandibular measurements were found (Table 2).

### Comparison of final forms

After expansion treatment (T1), there were statistically significant differences between the two groups in maxillary and mandibular measurements. Particularly, the transverse arch measurements in the MPE were greater than the untreated group except for mandibular interpremolar-1st width.

Both maxillary and mandibular arch depths were significantly smaller in the treated group (TG) when compared with controls (Table 2).

### Evaluation of treatment effects

In the MPE group, during the treatment (T1-T0), significant increases in all the variables for maxillary and mandibular arch widths were observed.

Maxillary measurements remarkably changed, while mandibular increases were slightly greater.

There was no significant difference in maxillary and mandibular arch depths in T1-T0 observation time (Table 2).

### Evaluation of normal growth increases

During the observation period of the control group (T1-T0), there were differences in all maxillary and mandibular transverse measurements with statistically significant levels smaller than MPE. There was no significant difference in maxillary and mandibular arch depths in T1-T0 observation time (Table 2).

### Comparison of treatment changes per year

The statistical comparison of the T1-T0 changes per year in MPE with respect to controls showed that treatment produced significantly greater increases in all the variables for both maxillary and mandibular arch widths when compared with the controls.

No statistically significant differences were found for maxillary and mandibular depth (Table 2).

	Initial					Final					Change After Treatment				Change/year After Treatment				
	Mpe Group T0		Control T0			Mpe Group T1		Control T1			Mpe Group T1-T0		Control T1-T0		Mpe Group T1-T0		Control T1-T0		
Cast Measure (mm)	Mean	SD	Mean	SD	P	Mean	SD	Mean	SD	P	Mean	P	Mean	P	Mean	SD	Mean	SD	P
<b>Maxillary arch width</b>																			
Intermolar	41,62	3,27	43,10	1,27	**	50,32	5,31	43,97	1,05	***	8,7	***	0,87	*	6,03	3,26	0,58	0,22	***
Interpremolar (2nd)	36,93	2,79	38,41	1,13	***	43,83	4,52	39,31	1,19	***	6,9	***	0,9	*	4,78	3,02	0,30	0,58	***
Interpremolar (1st)	32,67	2,24	33,47	1,15	**	40	4,41	34,51	1,10	***	7,33	***	1,04	**	4,83	3,53	0,69	0,66	***
Intercanine	28,62	2,26	29,61	1,61	***	32,33	2,13	30,84	1,36	*	3,71	***	1,23	**	2,73	1,23	0,82	0,71	***
<b>Mandibular arch width</b>																			
Intermolar	41,17	2,52	40,77	0,62	ns	43,29	2,63	41,23	0,61	***	2,12	**	0,46	*	1,65	0,85	0,30	0,16	***
Interpremolar (2nd)	35,27	2,67	35,27	0,96	ns	37,64	2,79	35,99	0,90	*	2,37	**	0,72	*	1,57	1,12	0,48	0,59	***
Interpremolar (1st)	29,88	1,85	30,01	1,18	ns	31,79	2,45	30,93	1,16	ns	1,91	**	0,92	*	1,35	0,92	0,61	0,61	*
Intercanine	24,45	1,50	23,86	0,81	ns	25,59	1,68	24,42	0,54	**	1,14	*	0,56	**	0,81	0,69	0,38	0,44	*
Maxillary arch depth	27,50	1,98	28,87	1,41	***	27,34	2,19	29,25	1,07	***	-0,16	ns	0,38	ns	-0,11	0,65	0,25	1,47	ns
Mandibular arch depth	23,59	1,87	25,31	1,04	ns	23	2,37	24,90	1,33	**	-0,59	ns	-0,41	ns	-0,39	0,98	-0,27	0,73	ns

\*P<0.05; \*\*P<0.01; \*\*\*P<0.001; ns: not significant

TABLE 2 Descriptive and inferential statistic.

## Discussion

The goal of this retrospective clinical study, conducted at the Department of Orthodontics of the Second University of Naples, was to assess the upper and lower dental changes in arch dimension in mixed dentition in patients who were treated by MPE compared with those observed in untreated growing subjects.

An original feature of this investigation was to achieve maxillary expansion following MPE. This procedure aims to obtain major skeletal and minor dental changes through the separation of the two maxillary halves during the first appointment, so that the forces delivered during the expansion are, therefore, completely directed on the bone structure.

### Comparison of starting form

The starting form showed significant differences between the two groups for all maxillary measurements as expected considering the treatment needs. All subjects in the MPE at T0 had significant reduced maxillary arch widths. Instead, mandibular arch widths did not present any significant reduction. On a separate note, the behaviour of arch depths in both the treated and untreated subjects should be elucidated.

Before treatment, maxillary arch depths were significantly smaller in the MPE when compared with the CG, whereas there was no significant difference in

mandibular measurement (Table 2).

### Comparison of final forms

All subjects in the TG, after MPE treatment (Table 2), had significantly increased maxillary arch widths respect to controls. The MPE maxillary expansion aimed to the overcorrection, to improve transverse arch dimensions and to reduce crowding, thus, the maxillary widths were greater in the TG than in the CG.

The final form showed significant differences between the TG and CG for all maxillary and mandibular measurements, with the only exception of the lower interpremolar-1st width increment. Also the maxillary and mandibular arch depths were significantly smaller in the TG when compared with CG.

### Comparison of treatment changes

In the upper arch, the intercanine width (3.71 mm) showed a smaller increase than the intermolar width (8.07 mm) (Table 2). As the appliance used in this study was not anchored to canine teeth, this result was not a surprise and was in agreement with the findings of several studies [Akkaya et al., 1998; Defraia et al., 2007; Defraia et al., 2008; Mossaz-Joëlon and Mossaz, 1989]. Contrarily to these findings, it has been reported that opening of midpalatal suture is greater in the anterior than posterior region [Bell and LeCompte, 1981; Biederman, 1973; Ekström et al., 1977; Wertz, 1970]. In

the lower arch, the increase in mandibular widths ranged between 1.14 mm to 2.37 mm (Table 2).

An important effect of MPE was the significant increase in the lower molar width, most likely due to a mandibular molar uprighting from a lower position of the tongue and a decreased buccal muscle force exerted on the lower dentition [Adkins et al., 1990; Akkaya et al., 1998; Perillo et al., 2011]. The uprighting was greater in the molar than in the canine area. At the end of the observation period, the increase for year in all the maxillary widths, ranging from 6.03 to 2.73 mm, in MPE was greater than in the CG varying from 0.82 to 0.58 mm. Even the mandibular widths in TG, ranged between 1.65 mm to 0.81 mm, showed an increase larger than the corresponding measurements in the CG, varying from 0.61 to 0.30 mm. During the observation time, small but not considerable losses in both maxillary (-0.11 mm) and mandibular (-0.39 mm) arch depths were recorded in the TG. Interestingly, the amount of reduction of mandibular arch depth (-0.39 mm) was greater than that observed in maxillary arch (-0.11mm). Moreover, the amount of reduction of maxillary and mandibular arch depths in the TG (-0.11 mm and -0.39) were greater than those observed in the CG (0.25 mm e -0.27 mm, respectively). The reduction of maxillary depth might be related to the increased transversal arch dimensions in the upper arch, whereas in the lower arch this result might be related to the increased mandibular arch widths concurrent with the maxillary expansion.

### Comparison with other authors

When analysing the literature, a comparison of the outcomes of this study can be performed at least indirectly with the results of Moussa [1995] and directly with those of other authors [McNamara et al., 2003; Geran et al., 2006] who used a similar measurement protocol with the same landmarks for cast analysis, whereas Moussa et al. used different definitions of arch width and depth, which included slightly different landmarks than those used in the present study. Moreover, Moussa and McNamara evaluated different treatment protocols that included a tooth/tissue-borne device for RME (Haas expander), Geran evaluated an acrylic splint expander bonded to the teeth, whereas this study evaluated the mixed palatal expansion using a Hyrax-type expander (MPE). Furthermore, a partial comparison could be made with the study of Sandstrom [1988], which focused only on the mandibular arch width changes concurrent with maxillary expansion, although a different definition of the mandibular intermolar and intercanine widths was used.

The findings of the present study were different from those reported by Moussa [1995], who focused on stability of maxillary and mandibular dental arch measurements changes and with no control group included for the comparison; moreover, the mean age of treated subjects was significantly different: 12.1 years versus 8.6 years. In this study, after MPE treatment,

maxillary and mandibular intermolar arch width increased 6.03 and 1.65 mm per year, respectively, whereas according to Moussa, after RME, the first increased 6.7 mm and the latter 2.0 mm during 3 years and 6 months of active therapy and contention.

In the studies of McNamara [2003] and Geran [2006], the treated group showed a mean increase of 4.4 mm in maxillary intermolar width due to active treatment lasting 2.5 years and 5.5 years, respectively. This increase was smaller than those reported by Moussa [1995] (6.7 mm/3.6 years) and smaller than that observed in this study (6.03 mm/per year). The same happened with the increase in maxillary intercanine width that was about 4.0 mm in the other previous studies, that is smaller than that observed in this study (2.73 mm/per year).

As to the mandibular intermolar width, our increase (1.65 mm/per year) was greater than those reported of about 1 mm [McNamara et al., 2003] 2.8 mm [Sandstrom et al., 1988], 2.0 mm [Geran et al., 2006] during different treatment times. As to the mandibular intercanine width, our increase of about 0.81 mm/per year was greater than that of 1.5 mm referred by all previous studies, although related to different treatment times. It could be emphasised that mandibular arch width increments in this study were observed in patients who underwent maxillary expansion without fixed appliances, unlike all four previous studies. This favourable outcome in the transversal dimensions of both arches, probably should be ascribed to the different treatment time of the expansion protocols (early mixed dentition) in this study and late mixed dentition or early permanent dentition in the study by McNamara [2003]. In agreement with Geran [2006], our findings showed that when maxillary expansion is performed during the early developmental phases, treatment outcomes are more skeletal.

## Conclusion

Maxillary expansion performed with MPE have to be considered as an effective treatment option to improve transverse arch dimensions and to gain arch space in order to correct posterior cross bite and/or to relieve mild-to-moderate tooth- size/arch discrepancies.

Approximately the increase in the upper arch width ranged from 3 to 6 mm/per year with concurrent 0.81 to 1.65 mm in lower arch width, as a possible lip-bumper side-effect of the maxillary expansion. These changes were significant, when compared with those of a sex- and age-matched untreated control group.

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