Original Article

Longitudinal Dental Arch Changes in the Mixed Dentition

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Abstract: The purpose of this study was to investigate dental arch changes that occurred during the mixed dentition in 30 normal occlusion children. Two analyses were done. The first one was at the age of early mixed dentition and the second at the age of late mixed dentition. Most width variables were greater in the males, and depth variables greater in the female subjects. A directionally larger left side of the maxilla and right side of the mandible were observed. Our findings indicate that most arch width dimensions are established in the early mixed dentition. We conclude that the period between the early and late mixed dentition is suitable for environmental factors to disrupt the ideal symmetrical developmental pattern because more growth and developmental changes occur after a relatively stabile period of deciduous dentition. (*Angle Orthod* 2003;73:509–514.)

Key Words: Dental arch width; Dental arch depth; Children; Asymmetry

INTRODUCTION

Dental arch dimensions change systematically during the period of intensive growth and development and less so in adulthood.[1] Many studies report a moderate increase in dental arch width[2–4] before the eruption of the permanent canines and a systematic decrease thereafter.[4,5] The intercanine and intermolar widths increase significantly between 6 weeks and 1 year of age in the mandible and between 6 weeks and 1 year, and 1 to 2 years of age in the maxilla as well as between the ages of 3 to 13 years.[6] Intercanine width remains stabile[4] or even decreases in the maxilla and mandible after 13 and 12 years of age, respectively.[6] In a 1972 longitudinal study, Knott[7] noticed changes in the average intercanine width between the deciduous and permanent dentition, but with high stability from the mixed to permanent dentition with considerable individual variation.

Some studies suggest that arch size has a modest genetic component and that arch length and width growth factors are largely independent.[8] It seems that the width of the dental arch is more genetically determined than its length. Moreover, in the last 50 years, the deciduous dental arch length was found more decreased than the width as a consequence of secular changes.[9] Dental arch asymmetry is a common finding in all Angle classes, and it can be the measure of an individual's developmental stability.[10,11]

In the mixed dentition, dental arch form and consequently the occlusion changes systematically because of tooth movement and the growth of the supporting bone.[12] Moyers et al[13] and van der Linden[14,15] suggested an important correlation of dental arch width increases with vertical growth of alveolar process. The upper alveolar processes diverge, whereas the lower alveolar processes are more parallel.

The clinical importance of predicting changes in dental arch form is obvious. By changing dental arch form without modifying it's dimension, different arch lengths may be achieved for each millimeter of incisor proclination.[16] The stability of treatment results and the formulation of the retention plans are of paramount importance for successful orthodontic therapy.[6] The purpose of this study was to investigate dental arch changes that occur during the mixed dentition.

MATERIALS AND METHODS

A total of 30 children, 17 males and 13 females, with normal occlusion were evaluated. Two analyses were done. The first was done at the age of the early mixed dentition (8–12 years) and the second at the age of late mixed dentition (10–14 years). The criterion for early mixed dentition was the eruption of the first molar or permanent incisors (or both). For the late mixed dentition, eruption of at least

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TABLE 1. Age and Sex Distribution of the Sample (in Years)

Sex	*n*	The First Measurement			The Second Measurement		
		Mean Age	SD	95% CI[a]	Mean Age	SD	95% CI[a]
Male	17	9.69	1.18	9.09–10.30	11.72	1.18	11.11–12.32
Female	13	9.73	1.49	8.93–10.63	11.72	1.49	10.83–12.61
Total	30	9.71	1.30	9.22–10.19	11.72	1.30	11.24–12.20

[a] CI indicates confidence interval.

TABLE 2. Tooth Landmarks

Tooth Landmarks	Description
I	Contact point of the central incisors
C	Protocone of canines
P1	Protocone of first premolar
P2	Protocone of second premolar
M1	Paracone of first molar
M2	Paracone of second molar

TABLE 3. Median Palatal Plane (MPP) Landmarks

MPP Landmarks	Description
A1	Intercestion of MPP and CC
A2	Intercestion of MPP and P1P1
A3	Intercestion of MPP and P2P2
A4	Intercestion of MPP and M1M1

one premolar or canine was assumed. Age and sex distribution of the sample are presented in Table 1.

Upper and lower dental casts were collected and digitized. Tooth landmarks were located on the contact points of the central incisors, protocones of the canines and premolars, and paracones of the molars (Table 2).

The median palatal plane (MPP) was used as a reference plane and defined in the maxilla by a line connecting the median incisive foramen and a raphe point at the depth of the first molar. Five points were marked on the MPP (Table 3).

To examine the characteristics of dental arch changes, the three parameters of arch width, depth, and arch segment length were observed. The width variable was measured as the maximum rectilinear distance between tooth landmarks and the MPP landmark for canines, premolars (deciduous molars), and the first permanent molars. Differences between maxillary and mandibular intercanine widths were calculated. The depth variable was calculated as the distance between neighboring MPP landmarks and that for the arch segment length variable as the distance between neighboring tooth landmarks (Table 4).

The original software from the Department of Orthodontics, Zagreb School of Dentistry and ''Emas'' company (Zagreb, Croatia) was used for gnathometric analysis.[17,18] Two different authors measured six casts both conventionally and using a computer. In the conventional method, a sliding caliper with a 0.1 mm precision was used. The average differences between the conventional and computer-based method ranged from 0.059 mm for width to 1.166 mm for the arch depth variable.[17]

TABLE 4. Definition of Acronyms for Width, Depth, and Arch Segment Variables

Variables	Description
W1R	Width from MPP to the right-hand C landmark
W1L	Width from MPP to the left-hand C landmark
W2R	Width from MPP to the right-hand P1 landmark
W2L	Width from MPP to the left-hand P1 landmark
W3R	Width from MPP to the right-hand P2 landmark
W3L	Width from MPP to the left-hand P2 landmark
W4R	Width from MPP to the right-hand M1 landmark
W4L	Width from MPP to the left-hand M1 landmark
D1	Depth from I to A1 landmark
D2	Depth from A1 to A2 landmark
D3	Depth from A2 to A3 landmark
D4	Depth from A3 to A4 landmark
L1R	Arch segment length from I to right-hand CC landmark
L1L	Arch segment length from I to left-hand CC landmark
L2R	Arch segment length from CC to P1 landmark on the right-hand side
L2L	Arch segment length from CC to P1 landmark on the left-hand side
L3R	Arch segment length from P1 to P2 landmark on the right-hand side
L3L	Arch segment length from P1 to P2 landmark on the left-hand side
L4R	Arch segment length from P2 to M1 landmark on the right-hand side
L4L	Arch segment length from P2 to M1 landmark on the left-hand side

Statistical analyses were performed using STATISTICA 5.1, '97 Edition (Institute for Anthropological Research, University of Zagreb, Systemcom, Zagreb). The arithmetic means and standard deviation of all variables in two samples (early mixed dentition and late mixed dentition) was calculated. Inferential statistical analyses were used to describe whether significant differences were present between male and female subjects and between early mixed dentition and late mixed dentition subjects. For all variables, the samples were tested sexwise with a *t*-test for independent samples. The normality assumption was evaluated by performing a normality test, and the equality of variances assumption was verified with the two-tailed *F* test. Therefore,

TABLE 5. Width Changes (in millimeters)

Variables	Maxilla					Mandible				
	Early Mixed Dentition		Late Mixed Dentition			Early Mixed Dentition		Late Mixed Dentition		
	Mean	SD	Mean	SD	*P* value[a]	Mean	SD	Mean	SD	*P* value
W1R	16.12	1.32	16.34	1.01	NS	13.31	1.79	13.52	1.23	NS
W1L	16.32	1.67	17.14	1.36	$P < .01$	13	1.84	12.95	1.11	NS
W2R	19.73	1.04	20.11	0.85	NS	17.13	1.43	17.25	0.99	NS
W2L	20.34	1.11	20.62	1.15	NS	16.91	1.29	17.04	1.09	NS
W3R	22.3	1.21	22.75	0.95	$P < .05$	20.32	1.33	20.03	1.33	NS
W3L	22.6	1.25	23.01	1.21	$P < .05$	20.12	1.38	19.79	1.32	NS
W4R	25.41	1.26	25.66	1.03	NS	23.4	1.14	23.67	1.19	$P < .05$
W4L	25.35	1.36	25.62	1.12	NS	23.49	1.35	23.37	1.12	NS

[a] NS indicates not significant.

TABLE 6. Depth Changes (in millimeters)

Variables	Maxilla					Mandible				
	Early Mixed Dentition		Late Mixed Dentition			Early Mixed Dentition		Late Mixed Dentition		
	Mean	SD	Mean	SD	*P* value[a]	Mean	SD	Mean	SD	*P* value
D1	9.54	1.44	9.17	1.11	NS	5.96	1.47	5.97	1.49	NS
D2	6.66	1.06	7.19	0.61	$P < .05$	6.25	0.81	5.95	0.65	$P < .05$
D3	7.63	1.24	6.94	0.85	$P < .01$	7.78	1.66	7.11	1.17	$P < .05$
D4	10.5	0.81	10.53	0.66	NS	10.26	0.93	10.51	0.87	NS

[a] NS indicates not significant.

TABLE 7. Dental Arch Segment Length Changes (in millimeters)

Variables	Maxilla					Mandible				
	Early Mixed Dentition		Late Mixed Dentition			Early Mixed Dentition		Late Mixed Dentition		
	Mean	SD	Mean	SD	*P* value[a]	Mean	SD	Mean	SD	*P* value
L1R	20.41	2.03	20.33	1.89	NS	16.28	2.51	16.38	1.91	NS
L1L	21.34	1.77	21.21	1.8	NS	16.08	2.93	15.39	1.56	NS
L2R	8.2	1.46	8.5	1.2	NS	7.87	1.17	7.59	1.13	NS
L2L	8.52	1.17	8.46	1.43	NS	7.86	1.47	7.76	0.86	NS
L3R	8.79	1.85	7.72	1.5	$P < .01$	9.16	2.05	8.18	1.32	$P < .01$
L3L	8.36	1.44	7.49	0.9	$P < .05$	9.41	2.22	8.37	1.67	$P < .05$
L4R	11.6	1.3	11.28	0.95	NS	11.29	1.24	11.79	1.06	NS
L4L	11.45	1.06	11.66	1.08	NS	11.71	1.39	11.93	1.64	NS

[a] NS indicates not significant.

the means of the two samples were tested for the differences using the *t*-test for independent samples.

RESULTS

In the early mixed dentition, only the mandibular arch segment length L4 exhibited a significant sex difference ($P = .01$). Longitudinal comparisons of width, depth, and dental arch segment–length changes between male and female subjects did not yield any statistically significant difference in the 2-year period.

Width changes

There was no significant difference in total intercanine width between early and late mixed dentition. A significant increase ($P < .01$) was observed for the left intercanine width segment in the maxilla. In the mandible, only W4R changed significantly ($P < .05$) between the two measurements. In the maxilla, there was a significant increase in width from the MPP to the second premolar on both sides. In the early mixed dentition, the mean difference between the maxillary and mandibular intercanine width was 6.1 mm (SD 2.4), which increased to 7.0 mm (SD 2.7) in the late mixed dentition.

Depth changes

A statistically significant difference was observed between dentitions in the canine-first deciduous molar and canine-first premolar depth (increases in the maxilla and

TABLE 8. Width and Arch Segment Asymmetry

	Maxilla		Mandible	
Variables	Early Mixed Dentition *P* value	Late Mixed Dentition *P* value	Early Mixed Dentition *P* value	Late Mixed Dentition *P* value
W1R-W1L	NS	$P < .01$	NS	$P < .01$
W2R-W2L	$P < .01$	$P < .05$	NS	NS
D1R-D1L	NS	$P < .05$	NS	$P < .05$

decreases in the mandible) as well as first-second deciduous molar and first-second premolar depth (decreases in both jaws). The intercanine depth increased slightly in the mandible and decreased in the maxilla (D1).

Dental arch segment length changes

A significant decrease in arch length between the first and the second premolar cusps was observed in both the maxilla and the mandible, with a greater decrease on the rightside ($P < .01$) as compared with the left side ($P < .05$). The intercanine arch length decreased slightly on both sides in the maxilla. A statistically insignificant increase of mandibular intercanine arch length was observed on the right side with a decrease on the left side.

Width and arch segment asymmetry

A statistically significant difference between the right and the left sides was found for only three of the variables presented in Table 8. In the early mixed dentition, there was no statistically significant difference between the right and the left sides in the mandible, whereas only one case (W2R-W2L) was observed in the maxilla. In the late mixed dentition, three variables indicated statistically significant left-right differences in the maxilla and two variables in the mandible. The intercanine width (W1R-W1L) exhibited the largest difference in both jaws ($P < .01$). In the maxilla, all of the left − right means were positive, except for the first molars, showing that the left side of maxilla was slightly larger than the right side. In contrast, the mandibular right side was slightly larger than the left, except for the first molar in the early mixed dentition.

A statistically significant dental arch asymmetry was observed only for the intercanine segment in the late mixed dentition in both jaws ($P < .01$). The left intercanine arch segment was larger in the maxilla, but the right intercanine arch segment was larger in the mandible.

DISCUSSION

There are a number of studies investigating changes in the dental arches during the period of growth and adulthood, and they provide strong evidence of individualized mechanisms that influence the form of the dental arch. Cassidy et al[8] showed different heritability ratios in the main arch parameters and presented an excellent analysis quantifying the genetic influence on dental arch form. Because the dental arch is under the influence of all supporting and neighboring structures as well as under a strong environmental influence, it is important to note some hereditary factors that are more difficult to treat in comparison to extrinsic influences. For phenotypic expression of all genetic and environmental influences, time is an important additional factor that should be considered.

The purpose of the present investigation was to analyze changes in dental arch width, depth, arch segment length, and arch asymmetry in a relatively short, yet a very important period for the developing occlusal relationship. The subjects with normal occlusion were investigated because the final aim of orthodontic treatment is normocclusion and because they can provide evidence for the physiological mechanisms of dental arch changes. Twenty variables for each dental arch were collected from dental casts of 30 children in the early and late mixed dentitions. Although some new methods (ie, new geometric morphometrics) provide excellent possibilities for morphological analysis,[19–23] distance measurements on dental casts were calculated because most clinicians are familiar with the method used in this study.

In many studies, maxillary or mandibular (or both) widths were larger in male than in female subjects.[8,24,25] However, in the present investigation, no width or depth variables indicated a statistically significant sexual dimorphism. This corresponds with the findings of Ferrario et al[26] who suggested that arch size was not influenced by sex in their sample. In general, most width variables were greater in male subjects and depth variables greater in female subjects. Arch segment lengths were similarly distributed between boys and girls. It seems that arch width is a dominant parameter in males and arch depth in females, but the results were not statistically significant.

For dental arch width, Cassidy et al[8] found that the highest heritability averaged around 60%. However, they found no statistically significant age effects for mandibular or maxillary arch widths. The results from the Michigan Growth Study[13–15] showed premolar width increases in both jaws, which were greater in the upper than in the lower dental arch. In this study, the premolar width increased in the upper and decreased in the lower dental arch. The findings of this study, as well as those of Bishara et al,[6] and of the Michigan Growth Study[13–15] indicate that most arch widths dimensions are established in the early mixed dentition. The minimal width changes that occur during the late mixed dentition are not a factor that should influence a treatment plan. On the contrary, changes in the growth direction—different in the maxilla and mandible—do have significant clinical application.[6,27]

A statistically significant decrease in the mandibular depth variables D2 and D3 is probably related to tooth substitution and Leeway space. In the period between the two measurements, an increase in only the canine-first deciduous molar (permanent premolar) depth in the maxilla was recorded. A decrease of the arch segment length was observed in the premolar region of both jaws, analogous to a depth decrease, but the findings for the canine-first deciduous molar (permanent premolar) length and depth are not the same. It seems that the increase of the D2 variable is linked to minimal changes in intercanine width. Arch segment length was not significantly changed as a result of the growth direction (forward and vestibular) of the canine-first deciduous molar (permanent premolar) segment. Consequently, it seems that the arch form has been changed slightly from catenary to parabola.

A directionally larger left side of the maxilla is a common finding in various studies.[8,28] However, in this sample, the mandibular right side was larger that the left side. Melnik[29] also documented that in the period of the mixed dentition, the right side dominates over the left side in the mandible, whereas the left side dominates in the maxilla. This could be in keeping with chewing habits on the right side. Moreover, cranial analysis reveals that the right side of the calvaria is larger than the left side. The same study reports converse (left $>$ right) asymmetry in maxilla as the compensation of the calvarial side difference,[28] and our findings also suggest that the mandible follows the cranial growth pattern.

An interesting finding was the increased asymmetry in the period of the mixed dentition. As can be seen from the results, minimal asymmetry was observed in the period of the early mixed dentition. In the late mixed dentition, asymmetry was observed in more bilateral variables. This implies that the period between early and late mixed dentition is suitable for an increase in asymmetry because more growth and developmental changes occur after a relatively stabile period of deciduous dentition. Earlier studies[30,8] documented a minor but noticeable important genetic factor, further implying dominance of environmental influences in development of dental and dental arch asymmetry. However, it seems that genetic control over symmetrical development is greater in the early mixed dentition, whereas environmental factors seem to have greater influence in disrupting the pattern of ideal symmetrical development in the late mixed dentition.

CONCLUSIONS

The growth and development of the occlusion is a synthesis of form and function, as well as of facial growth. The findings of this study suggest that dental arch dimensions are more defined by tooth eruption and less so by the growth of the supporting bone during the mixed dentition. In the early mixed dentition, intercanine relations are primarily defined by the early onset of mandibular growth. However, the skeletal growth of the maxillofacial complex in the late mixed dentition is not always predictable. The period between early and late mixed dentition is suitable for environmental factors to disrupt the pattern of ideal symmetrical development of dental arch form. Because a number of orthodontic treatments may be planned or applied in the period of early or late mixed dentition, the definition of the exact stage of the mixed dentition is of utmost importance for deciding upon and administering the appropriate orthodontic therapy.

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