European Journal of Orthodontics 19 (1997) 681–689

Craniofacial parameters during growth from the deciduous to permanent dentition—a longitudinal study

V. Gaži-Čoklica*, Ž. Muretić*, R. Brčić**, J. Kern*** and A. Miličić*

*School of Dental Medicine, University of Zagreb, **Velika Gorica Health Center, Velika Gorica and ***Andrija Štampar School of Public Health, Zagreb, Croatia

SUMMARY Data on the dynamics of craniofacial growth, obtained by simple non-invasive measurements, are scarce in comparison with those collected by cephalometric methods.

The aim of this study was to measure a number of craniofacial parameters, and to evaluate their changes during transition from the deciduous to the permanent dentition. A sample of 61 subjects (32 boys and 29 girls) were followed longitudinally by annual examination from an initial mean age of 4.7 years to a final mean age of 11.8 years. Conventional anthropometric instruments were employed to measure six craniofacial variables: G–Op, Eu–Eu, Zy–Zy, Go–Go, N–Gn and N–Pr. The data were analysed using basic summary statistics and a longitudinal regression model.

A difference between males and females was found for all variables during the study period. During the transition from deciduous to mixed dentition (4.7–7.5 years), the cranial breadth and length (Eu–Eu and G–Op) decreased followed by an increase during the mixed dentition. All other parameters showed a continuous increase, which was highest for the variables defining facial height.

Introduction

The dynamics of growth and development of the craniofacial complex are difficult to evaluate due to interactions between function and shape, suggesting that postnatal growth does not follow a uniform line, but rather an irregular progression dependent on time and magnitude of change.

Approximately two-thirds of orthodontic anomalies are caused by improper growth and development in the period of the deciduous and mixed dentition. Baseline data concerning the fundamental trends and dynamics of craniofacial change are of the utmost importance for correct diagnosis and treatment planning.

In comparison with data available from cephalometric studies (e.g. Savara and Singh, 1968; Broadbent *et al.*, 1975; Woodside and Linder-Aronson, 1979; Bishara, 1981; Sinclair and Little, 1985; Lundström *et al.*, 1987; Anderson and Popovich, 1989; Nanda *et al.*, 1990; Foley and Mamandras, 1992), only a few reports have been published regarding non-invasive measurement of the craniofacial complex (Farkas *et al.*, 1988; Legović *et al.*, 1991; Muretić *et al.*, 1992).

The aim of this study was to investigate, using a longitudinal method, the growth of the craniofacial region by measuring a number of basic craniofacial parameters during the transition from the deciduous and mixed to the permanent dentition.

Subjects and methods

The sample consisted of 61 subjects, 32 boys and 29 girls, mean age 4.7 years (decimal age) at initial examination and 11.8 years at the end of the study. The subjects were followed from the complete deciduous dentition, on an annual basis, to the completion of the permanent dentition, a total of six examinations.

Six craniofacial variables (Figure 1) defined by the anthropometric points of glabella, opisthocranion, euryon, zygion, gonion, nasion and prosthion were determined: head length (G–Op), head breadth (Eu–Eu), upper face width (Zy–Zy), lower face width (Go–Go), total face height (N–Gn) and upper face height (N–Pr).

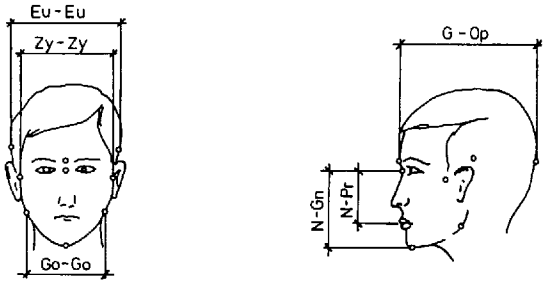

Figure 1 Lateral and frontal view of the head showing anthropometric points and measurement.

All variables were measured and recorded, by the same examiner, in all study subjects, with the exception of the upper height and lower face width at the initial examination. At each examination, cephalic (CI) and facial (FI) indices were calculated (CI = Eu–Eu × 100/G–Op; FI = Zy–Zy × 100/N–Gn; Martin and Saller, 1957; Salzmann, 1966) from the above-mentioned original variables.

Measurements were performed using a sliding gauge and an anthropologic cephalometer with a measuring diameter of 0–300 mm and accuracy of 0.5 mm.

Statistical analysis was performed using basic statistical parameters (mean = $\bar{x}$, standard deviation = SD) and a Student's *t*-test with an SPSS program. The coefficient of variability (CV) was applied to determine differences in variability of parameters within the sample population (Petz, 1970). For forecasting the value of any particular variable on the basis of age, a longitudinal regression model was used (Goldstein, 1986; Buschang *et al.*, 1989; Hoeksma and van der Beek, 1991).

Results

The results are shown in Tables 1–4 and Figures 2–8.

Throughout the study period, male subjects had larger values than females (Tables 1 and 2, and Figures 2–7). The differences in the mean values obtained were not statistically significant except for: upper face width (Zy–Zy) in the period of the deciduous dentition; lower face width (Go–Go) at the third and fourth examinations, and at the time of completion of the permanent dentition (sixth examination); upper width (Zy–Zy), and both face heights (N–Gn and N–Pr) at the sixth examination.

Head breadth

The head breadth (Eu–Eu) decreased in 70.5 per cent of the subjects (1.59 mm; 1.12 per cent) between the first and second examination, with slight differences between the males and females (Tables 1 and 3; Figure 2) After the second examination, head breadth showed a steady and continuous increase until the fourth examination, this being more marked in females than males. In females, the growth was most significant in the period between the age of 10.7 and 11.8. In males, the initial value was exceeded at the age of 10.7, and in females at the end of the study period. When the changes were analysed throughout the study period, they were found to be very small. The difference between the means at the first and sixth examination was only 0.75 mm (0.53 per cent).

Head length

A decrease in head length (G–Op) was found in the transition from the deciduous to the initial stage of mixed dentition for 75.41 per cent of the sample. The difference between the means at the first and second examination was only 0.15 per cent (Tables 1 and 3; Figure 3). Between the second and third examination, the head length remained static. This was followed by a more intensive increase (especially in females), so that for females the original value measured was achieved between the third and fourth examination, and in males between the fourth and fifth examination. The total change in this dimension throughout the study period was small (176.02–178.91 mm), with a recorded increase of only 2.89 mm (1.62 per cent). If the changes that occurred from the beginning to the end of the mixed dentition are considered, the average increase was 4.63 mm (2.59 per cent).

Facial width

The upper face width (Zy–Zy) showed a continuous increase throughout the study period, with statistically significant differences in means for older children, especially for females (Table 1; Figure 4). The total difference between

Table 1 Means and standard deviations of the variables investigated, in total and according to sex, in the six defined periods of observation.

		n	Eu–Eu	G–Op	Zy–Zy	Go–Go	N–Gn	N–Pr
1	Σ	61	141.69	176.02	111.80		86.46	
			5.78	8.60	4.83		4.07	
	M	32	143.84	179.44	112.47		88.13	
			6.03	8.47	5.30		4.18	
	F	29	139.31	172.24	111.07		84.62	
			4.47	7.14	4.21		3.08	
2	Σ	61	140.10	174.28	113.30	87.26	88.05	57.00
			5.71	8.09	4.85	3.87	4.61	3.23
	M	32	142.50	177.41	114.75	88.44	89.97	58.27
			5.70	7.49	5.27	3.76	4.71	3.31
	F	29	137.45	170.83	111.69	85.97	85.93	55.60
			4.48	7.39	3.82	3.63	3.47	2.52
3	Σ	61	140.31	174.33	114.79	87.57	88.67	57.84
			6.07	7.92	4.80	3.89	4.36	3.83
	M	32	142.66	177.41	116.34	88.47	90.38	59.14
			6.57	7.44	5.18	3.80	4.56	4.27
	F	29	137.72	170.93	113.07	86.59	86.79	56.430
			4.24	7.11	3.73	3.81	3.28	
4	Σ	61	140.74	176.23	116.30	89.11	91.31	59.26
			5.52	8.14	4.98	4.76	4.56	3.87
	M	32	143.06	179.19	118.00	90.09	92.59	60.31
			5.74	7.85	5.53	4.34	4.79	4.38
	F	29	138.17	172.97	114.41	88.03	89.90	58.10
			3.97	7.27	3.50	5.05	3.90	2.85
5	Σ	61	141.30	177.61	118.67	90.79	93.66	61.21
			5.66	8.10	5.05	4.55	5.00	4.13
	M	32	143.94	180.72	120.41	92.03	95.03	62.41
			5.65	7.96	5.44	4.45	5.54	4.69
	F	29	138.38	174.17	116.76	89.41	92.14	59.90
			4.08	6.86	3.84	4.31	3.89	2.96
6	Σ	55	142.44	178.91	120.56	92.49	95.04	61.75
			5.64	7.84	4.85	4.48	5.54	3.78
	M	29	144.41	182.28	121.31	93.28	96.34	62.64
			5.65	8.13	5.46	4.64	6.31	4.38
	F	26	140.23	175.15	119.73	91.62	93.58	60.77
			4.83	5.58	4.00	4.21	4.28	2.74

Values are means, with standard deviations given below.

mean values at the beginning and at the end of the period was 8.76 mm (7.27 per cent)—slightly greater in males than in females ($P \leq 0.01$). The difference between males and females was statistically significant in study periods 2, 3, 4 and 5 (Table 2).

In comparison with the upper face width, lower face width (Go–Go) showed a smaller increase which was statistically significant ($P \leq 0.05$) (Tables 1 and 3; Figure 5). From the beginning of the period of the mixed dentition to the last examination at the time of permanent dentition, the increase in face width was 5.23 mm (5.65 per cent), and was more pronounced in

Table 2 Differences in means according to sex and their significance.

	Eu–Eu	G–Op	Zy–Zy	Go–Go	N–Gn	N–Pr
1	4.53	7.20	1.40		3.51	
	3.36**	3.60**	1.17		3.77**	
2	5.05	6.58	3.06	2.47	4.04	2.67
	3.85**	3.44**	2.62**	2.63**	3.88**	3.87**
3	4.94	6.48	3.27	1.88	3.59	2.74
	3.53**	3.48**	2.84**	1.93	3.59**	3.01**
4	4.89	6.22	3.59	2.06	2.69	2.21
	3.91**	3.21**	3.07**	1.70	2.42	2.35*
5	5.56	6.55	3.65	2.62	2.89	2.51
	4.45**	3.45**	3.04**	2.34*	2.37*	2.54*
6	4.18	7.13	1.58	1.66	2.76	1.87
	2.96**	3.81**	1.23	1.39	1.93	1.93

Values represent $\bar{x}_M - \bar{x}_F$, with t-values given below.

Table 3 Absolute and relative differences in means of the variables between examinations.

		Eu–Eu	G–Op	Zy–Zy	Go–Go	N–Gn	N–Pr
1–2	%	1.12	0.99	1.34		1.83	
	Σ	–1.59	–1.74	1.50		1.59*	
	M	–1.34	–2.03	2.28		1.84	
	F	–1.86	–1.41	0.62		1.31	
2–3	%	0.15	0.03	1.30	0.35	0.70	1.45
	Σ	0.21	0.05	1.49	0.31	0.62	0.84
	M	0.16	0.00	1.59	0.03	0.41	0.87
	F	0.27	0.10	1.38	0.62	0.86	0.80
3–4	%	0.31	1.08	1.30	1.73	2.89	2.40
	Σ	0.43	1.90	1.51	1.54	2.64**	1.42*
	M	0.40	1.78	1.66	1.62	2.21	1.17
	F	0.45	2.04	1.34	1.44	3.11**	1.70*
4–5	%	0.40	0.78	2.00	1.85	2.51	3.19
	Σ	0.56	1.38	2.37**	1.68*	2.35**	1.95**
	M	0.88	1.53	2.41	1.94	2.44	2.10
	F	0.21	1.20	2.35	1.38	2.34	1.80*
5–6	%	0.99	0.73	1.57	1.84	1.45	0.87
	Σ	1.14	1.30	1.89*	1.70*	1.38	0.54
	M	0.47	1.56	0.90	1.25	1.31	0.23
	F	1.85	0.98	2.97**	2.21	1.44	0.87

Table 4 Means and standard deviations of cephalic and facial indices, in total and according to sex, in the six defined periods of observation.

		CI	FI
1	Σ	80.70	77.43
		5.30	4.25
	M	80.40	78.47
		6.06	4.38
	F	81.02	76.29
		4.38	3.85
2	Σ	80.56	77.80
		4.95	4.35
	M	80.51	78.52
		5.52	4.84
	F	80.60	77.00
		4.33	3.66
3	Σ	80.65	77.34
		5.04	4.19
	M	80.60	77.79
		5.86	4.56
	F	80.70	76.84
		4.06	3.75
4	Σ	80.03	78.60
		4.80	4.09
	M	80.03	78.57
		5.42	4.48
	F	80.02	78.62
		4.10	3.70
5	Σ	79.71	79.0
		4.64	4.63
	M	79.83	79.04
		5.23	5.14
	F	79.83	79.04
		3.99	4.07
6	Σ	79.75	78.91
		4.49	4.89
	M	79.41	79.53
		5.18	5.74
	F	80.13	78.21
		3.63	3.72

Values are means, with the standard deviations given below.

girls, where a more intensive increase was again observed at the last examination.

Face heights

The face heights showed the greatest relative increase in the defined period of observation

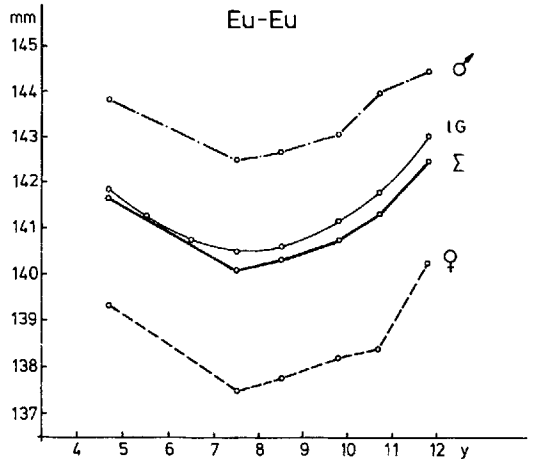

Figure 2 Means of Eu–Eu variable during growth (I G – means assessed according to Goldstein longitudinal analysis).

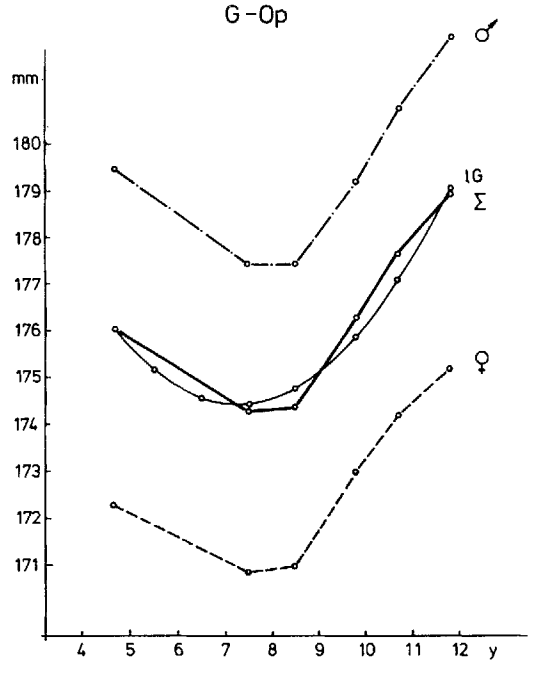

Figure 3 Means of G–Op variable during growth (I G— means assessed according to Goldstein longitudinal analysis).

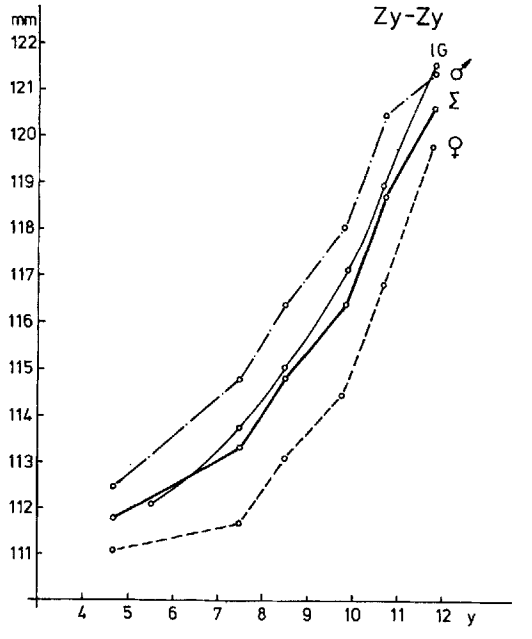

Figure 4 Means of Zy–Zy variable during growth (I G— means assessed according to Goldstein longitudinal analysis).

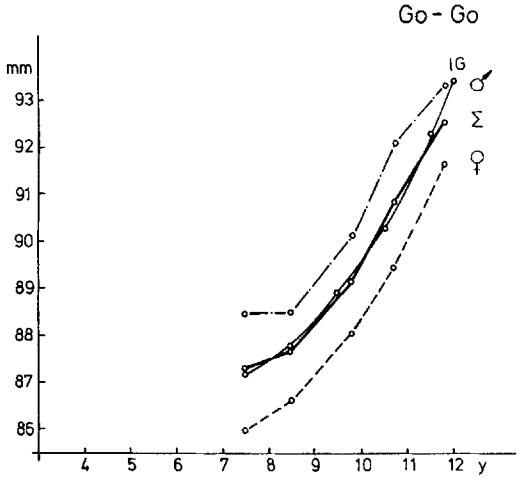

Figure 5 Means of Go–Go variable during growth (I G— means assessed according to Goldstein longitudinal analysis).

(Table 1; Figures 6 and 7). Total face height (N–Gn) showed a statistically significant ($P \leq 0.01$) increase of 8.5 mm (9.03 per cent). The difference was more pronounced in females. Statistically significant differences were also noted between the first and second, third and fourth, and fourth and fifth examinations. Males showed facial length measurements that were higher than females ($P \leq 0.01$), although the

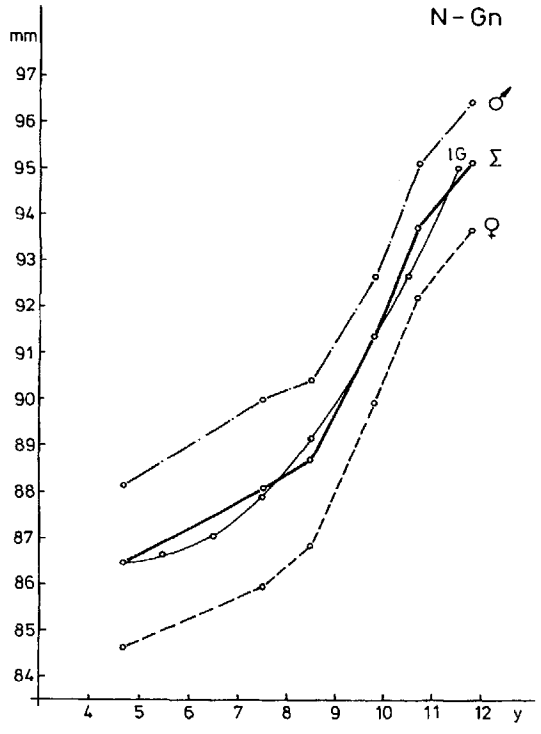

Figure 6 Means of N–Gn variable during growth (I G—means assessed according to Goldstein longitudinal analysis).

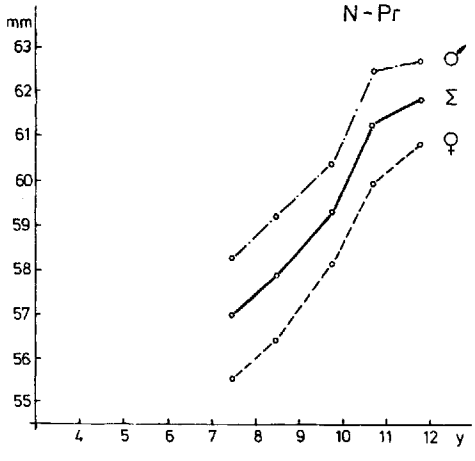

Figure 7 Means of N–Pr variable during growth.

females showed a more marked increase of the mentioned parameter (Tables 2 and 3).

The upper face height exhibited a marked

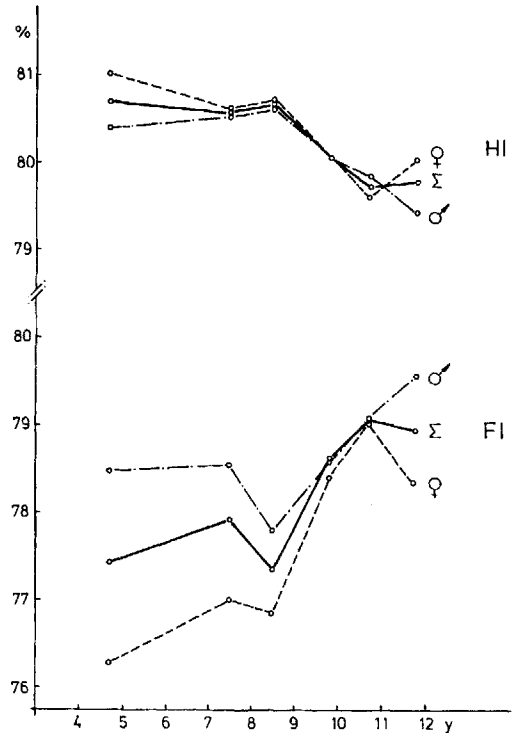

Figure 8 Means of cephalic (CI) and facial (FI) indices during growth.

increase. During the mixed dentition, it was 4.75 mm (7.69 per cent), and was more pronounced in females. The difference between males and females was statistically significant at all examinations with the exception of the final stage.

The analysis of variability for the whole sample showed lower coefficients in girls than in boys. The lowest coefficients of variability were obtained for head breath (Eu–Eu = 2.87–4.61 per cent), and were highest for upper face height (N–Pr = 4.51–7.51 per cent). For the upper face width (Zy–Zy), a decrease in variability with age was observed, whereas an opposite finding was obtained for face height (N–Gn).

Craniofacial indices

Analysis of cephalic indices pointed to mesocephaly in both sexes (Table 4; Figure 8). A difference between males and females was observed in the period of the deciduous dentition and at the completion of the permanent dentition,

as girls showed a larger head breadth. In the last period studied, the increase in head width in females led to an abrupt increase in the cephalic index, whereas in males its value continued to decline.

The mean values for the facial index indicated euryprosopy (in some examinations even hypereuryprosopy). Sexual dichotomy was also observed.

A significant variability of cephalic and, to a lesser extent, of facial indices was recorded.

The longitudinal regression analysis showed significant regression coefficients (as assessed on the basis of individual growth curves) at a confidence level of 5 per cent, with the exception of the variables exhibiting high variability, i.e. cephalic and facial indices (CI, FI) and upper face height (N–Pr). The growth curves obtained on the basis of the results (l G ; Figures 2–6) were found to correspond well with the curves obtained on the basis of the mean values recorded on each examination. According to interpretation of regression coefficients (Goldstein, 1986), correlations between coefficients showed that a higher initial value of certain dimensions implied slower growth.

Discussion

The methods employed in this study are seldom used today, so that comparisons of our results with those using different methodologies (cross-sectional, longitudinal or radiographic) are not aviable. Thus, our conclusions should be interpreted with some reservations.

Many authors (Horowitz and Hixon, 1966; Jones and Meredith, 1966; Singh *et al.*, 1967; Ingerslev and Solow, 1975; Chang, 1988; Farkas *et al.*, 1992) have recorded quantitative differences between males and females for a number of craniofacial measurements. In contrast Athanasiou *et al.* (1992) reported a lack of sexual differences for cephalometric variables. It has been stated that sexual dimorphism is mainly an expression of secondary sexual characteristics that occurs after puberty and during adolescent years, and that differences on transverse dimensions are limited to zygomatic prominences, mastoid processes and external mandibular angle (Broadbent *et al.*, 1975).

The most marked growth in males was observed in the period between the age of 9.8 and 10.7 years, for all variables, while in females the head length and face heights showed a marked increase in the period 8.5–10.7 years, probably due to beginning of the prepubertal growth spurt (Marshall and Tanner, 1970; Prebeg, 1975).

The decrease in head dimensions (Eu–Eu, G–Op) between first and second examinations, recorded in this study, is not in agreement with the findings previously reported (Gaži-Čoklica, 1977, 1984). However, considering that a cross-sectional method was used in the previous studies, and that the changes found in this study were small, it appears that the cross-sectional method could 'mask' the difference.

The upper face width (Zy–Zy) and lower face width (Go–Go) were different for males and females at the final examination. This could be attributed to a considerable increase of this measurement in girls in the period between 10.7 and 11.8 years, which was not seen in boys. A similar finding was recorded in cephalic width (Eu–Eu).

The face heights (N–Gn and N–Pr) showed the highest coefficients of variability, in agreement with other studies (Woodside and Linder-Aronson, 1979; Foley and Mamandras, 1992).

The findings of this study are consistent with those reported previously (Gaži-Čoklica, 1977, 1984; Gaži-Čoklica *et al.*, 1989, 1990, 1991; Farkas *et al.*, 1992). Higher cephalic index values in adult females of the same population were also recorded by Muretić *et al.* (1992).

In the younger age groups, faces were narrower and longer in boys. A decrease in facial index, i.e. face widening, between 7.5 and 8.5 years, was recorded in both sexes, but was more marked in males. This was probably due to early intensive growth of upper face width than of face height. With time, the face narrowed in both males and females (more marked in females), so that the difference gradually diminished and almost disappeared at the age of 9.8–10.7 years. In the last period examined, the difference recurred because of a marked decline in the facial index in

girls, whereas it continued to rise in boys, probably due to a more intensive peripubertal growth of upper face width in females, and face height in males. A finding of euryprosopy in boys and girls, and a higher value of facial indices in females, has been reported by Muretić *et al.* (1992).

Conclusions

The results of the study suggest the following conclusions.

1. A difference between males and females was observed for all variables throughout the study; males had statistically significantly larger values than females.
2. On transition from deciduous to mixed dentition, the dimensions of head breadth and head length showed a slight decrease in 70–75 per cent of cases, whereas in the period of the mixed dentition an increase in these dimensions was recorded.
3. All facial parameters showed a continuous increase with time which was statistically significant at the 1 per cent level.
4. Variability was greater in boys than in girls; it was lowest for the variable of head breadth and highest for upper face height.
5. An analysis of craniofacial indices indicated mesocephaly and euryprosopy in the study subjects during the defined period.
6. The longitudinal regression analysis produced results consistent with the analysis of means and pointed to a more rapid gain in all variables in children with lower initial values.

Address for correspondence

Professor Ž. Muretić
School of Dental Medicine
University of Zagreb
Gundulićeva 5
10000 Zagreb
Croatia

References

Anderson D, Popovich F 1989 Correlations among craniofacial angles and dimensions in Class I and Class II malocclusions. Angle Orthodontist 59: 37–42

Athanasiou A E, Droschl H, Bosch C 1992 Data and patterns of transverse dentofacial structure of 6- to 15-year-old children. A posteroanterior cephalometric study. American Journal of Orthodontics and Dentofacial Orthopedics 101: 465–471

Bishara S E 1981 Longitudinal cephalometric standards from 5 years of age to adulthood. American Journal of Orthodontics 79: 35–44

Broadbent B H Sr, Broadbent G H Jr, Golden W H 1975 Bolton standards of dentofacial developmental growth. C V Mosby Co., St Louis

Buschang P H, Tanguay R, Demirijan A, La Palme, Goldstein H 1989 Modelling longitudinal mandibular growth: Percentiles for gnathion from 6 to 15 years of age in girls. American Journal of Orthodontics and Dentofacial Orthopedics 95: 60–66

Chang H P 1988 A morphological study on the craniofacial complex and dental arch of Chinese children with primary dentition. Journal of Osaka Dental University 22: 55–100

Farkas L G, Ngim R C, Lee S T 1988 The four dimensions of the face: a preliminary report of growth potential in the face of the Chinese population of Singapore. Annals of the Academy of Medicine 17: 319–327

Farkas L G, Posnick J C, Hreczko T M 1992 Growth patterns of the face: a morphometric study. Cleft Palate-Craniofacial Journal 29: 308–315

Foley T F, Mamandras A H 1992 Facial growth in females 14 to 20 years of age. American Journal of Orthodontics and Dentofacial Orthopedics 101: 248–254

Gaži-Čoklica V 1977 Korelacija izmedu definiranih kraniofacijalnih raspona i mjera maksile. MS thesis, University of Zagreb, Croatia

Gaži-Čoklica V 1984 Prilog iznalaženju bioloških vrijednosti kraniofacijalnih mjera, temeljenih na kefalometrijskim parametrima kod ispitanika u toku rasta. Doctoral dissertation, University of Zagreb, Croatia

Gaži-Čoklica V, Brčić R, Miličic A, Šlaj M 1989 Dinamika rasta kraniofacijalnih struktura - longitudinalna studija. Acta Stomatologica Croatica 23: 3–12

Gaži-Čoklica V, Miličić A, Šlaj M, Brčić R 1990 Dinamika rasta četiri osnovne kraniofacijalne dimenzije s obzirom na ortodontski nalaz—longitudinalna studija. Acta Stomatologica Croatica 24: 27–38

Gaži-Čoklica V, Brčić R, Miličić A, Šlaj M 1991 Analiza kraniofacijalnih promjena od mlijčne do prve etape mješovite denticije. Bilten UOJ 2: 13–20

Goldstein H 1986 Efficient statistical modelling of longitudinal data. Annals of Human Biology 13: 129–141

Hoeksma J B, van der Beek M C J 1991 Multilevel modelling of longitudinal cephalometric data explained for orthodontists. European Journal of Orthodontics 13: 197–201

Horowitz S L, Hixon E H 1966 The nature of orthodontic diagnosis. C V Mosby Co., St Louis

Ingerslev C H, Solow B 1975 Sex differences in craniofacial morphology. Acta Odontologica Scandinavica 33: 85–94

Jones B H, Meredith H V 1966 Vertical change in osseous and odontic portions of human face height between the ages of

five and fifteen years. American Journal of Orthodontics 52: 902–921

Legović M, Poropat-Pejković K, Fabac E 1991 Crescita di determinate dimensioni cranio-facciali considerando lo sviluppo della normoocclusione e malocclusione nel periodo della dentazione mista. Minerva Stomatologica 42: 333–339

Lundström A, Woodside D G, Popovich F 1987 Panel assessments of facial profile related to mandibular growth direction. European Journal of Orthodontics 9: 271–278

Marshall W A, Tanner J M 1970 Variations in pattern of pubertal changes in boys. Archives of Disease in Childhood 45: 13–23

Martin R, Saller K 1957 Lehrbuch der Antropologie, Band I. Fischer, Stuttgart

Muretić Ž, Sergl H G, Schmidt J, Gaži-Čoklica V, Šlaj M 1992 Morphological cephalometric differences between two European populations. Acta Medica Croatica 46: 79–84

Nanda R S, Meng H, Kapila S, Goorhuis J 1990 Growth change in soft tissue facial profile. Angle Orthodontist 60: 177–190

Petz B 1970 Osnovne statisticke metode. Jugoslavenska akademija znanosti i umjetnosti, Zagreb

Prebeg Ž 1975 Dob menarhe u zagrebačkih učenica. Liječnički vijesnik 97: 379–382

Salzmann J A 1966 Practice of orthodontics. J B Lippincott Co., Philadelphia

Savara B S, Singh I J 1968 Norms of size and annual increments of seven anatomical measurements of maxillae in boys from three to sixteen years of age. Angle Orthodontist 44: 507–512

Sinclair P M, Little R M 1985 Dentofacial maturation of untreated normals. American Journal of Orthodontics 88: 146–156

Singh I J, Savara B S, Newman M T 1967 Growth in the skeletal and nonskeletal components of head width from 9 to 14 years of age. Human Biology 39: 182

Woodside D G, Linder-Aronson S 1979 The channelization of the upper and lower anterior face heights compared to population standard in males between ages 6–20 years. European Journal of Orthodontics 1: 25–40