European Journal of Orthodontics 34 (2012) 418–426
doi:10.1093/ejo/cjr025
Advance Access Publication 28 February 2011

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Dental arch width, overbite, and overjet in a Finnish population with normal occlusion between the ages of 7 and 32 years

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SUMMARY The aims of the present study were to provide data on growth changes in the dental arches from age 7 to 32 in Finns with untreated normal Angle Class I occlusions. The material consisted of 33 series of dental casts of 18 women and 15 men. The subjects had been examined and study models taken at the ages of 7, 10, 12, 15, and 32. Dental arch width, overbite, and overjet were measured. Our longitudinal findings show that both the dental arches of young adults are slightly narrowed from adolescence to 32 years of age. All increases in width dimensions took place before 15 years of age. The means of the changes were mostly small, in the order of 0.5 to a few millimetres. Variability in age changes was considerable. In both genders, each variable increased in some subjects and decreased in others during every age interval. Differences between growth changes in the mesial, distal, and gingival intermolar widths indicate that both the maxillary and the mandibular first molars rotate mesiolingually and that the maxillary first molars also become more upright during late occlusal development.

We expect the present findings of the changes occurring in the arch dimensions of subjects with untreated normal occlusions to help clinicians in following up occlusal development, choosing an optimal treatment time, and making orthodontic treatment and retention plans. However, because of the wide variability, accurate prediction of future development cannot be made on the individual level.

Introduction

The success of orthodontic treatment depends in part on growth changes in dentition and the face. Sufficient basic information on the magnitude and timing of growth in the dental arches is a prerequisite for making an orthodontic diagnosis and for planning treatment. Growth during childhood and adolescence has been studied on untreated random samples (Moorrees, 1959; Sillman, 1964; Knott, 1972; Prahl-Andersen *et al.*, 1979), on untreated normal occlusion samples (Sinclair and Little, 1983; Bishara *et al.*, 1997; Šlaj *et al.*, 2003; Arslan *et al.*, 2007; Thilander, 2009), and also following orthodontic treatment (Herberger, 1981; Udhe *et al.*, 1983; Little *et al.*, 1988). Norms based on these studies are used as guidelines when planning orthodontic treatment of growing individuals.

Increasing numbers of adults are seeking orthodontic treatment, and there is a growing interest in orthognathic surgery and treatment with dental implants. The stability of treatment results is essential for both patients and clinicians. Post-treatment changes occur, however, and it is not clear to what extent they should be considered as relapses or as normal changes over time. Changes in the dental arches that occur during adulthood have been the subject of several studies (Bishara *et al.*, 1989, 1994; Bondevik, 1998; Carter and McNamara, 1998; Henrikson *et al.*, 2001), but there is a need for additional information on the extent and timing of long-term growth changes in orthodontically untreated dental arches.

In the present longitudinal study, growth changes in the dental arches were investigated from age 7 to 32. The first aim was to provide age- and gender-specific data on the width dimensions of the dental arches and on overjet and overbite in Finns with untreated normal occlusions. The second aim was to study growth changes in these dimensions and possible changes in the positions of the first molars with increasing age. The third aim was to find out if changes in the anterior and posterior widths of the dental arches are associated with each other or with overjet and overbite.

Material and methods

The subjects had participated in a longitudinal investigation to identify children requiring orthodontic treatment

(Heikinheimo, 1989). The original sample consisted of 200 Finnish children, 100 girls and 100 boys, born in 1967. They were pupils from seven schools situated in different parts of the city of Jyväskylä in Central Finland. The subjects were examined at the ages of 7, 10, 12, and 15 years. Alginate impressions for the study models were taken by two specialists in orthodontics. The casts were made of dental stone and orientated in the intercuspal position with the aid of a wax index. In 1999, at the age of 32, the participants were contacted again and offered an opportunity for an examination. The examination at the age of 32 was attended by 72 women and 63 men.

For the present study, we chose all the subjects with Class I occlusion from 7 to 32 years of age, who filled following criteria: no congenitally missing teeth and no loss of permanent teeth, no tooth migrations because of premature loss or caries of primary teeth, no crowding at the age of 15, no crossbites or scissorsbites, and no orthodontic treatment. The final material consisted of 33 series of dental casts of 18 women and 15 men. All 33 subjects had dental casts taken at the ages of 7, 12, 15, and 32.

Variables recorded on the models:

1. Intercanine width: The distance between cusp tips of the deciduous or permanent canines and the distance between the canines measured at the intersection of the gingival margin along the long axis of the teeth.
2. Interbicuspid width: The distance between the mesiolingual cusps of the deciduous first molars or the lingual cusps of the first bicuspids and the distance between the mesiolingual cusps of the deciduous second molars or the lingual cusps of the second bicuspids.
3. Intermolar width: The distance between the mesiolingual cusps of the first permanent molars, the distance between the distolingual cusps of the first permanent molars, and the distance between the first molars measured at the gingival level by the mesiolingual cusp tips.
4. Overjet: The distance from the most prominent point on the incisal edge of the upper central incisors to the labial surface of the lower central incisors, measured parallel to the upper occlusal surface.
5. Overbite: Vertical overlap of the central incisors. The incisal edge of the maxillary central incisor with the greatest degree of overlap was projected onto the labial surface of the mandibular central incisor parallel to the upper occlusal surface and marked with a sharp pencil and the distance was measured.

To ensure identical longitudinal locations of landmarks, all the casts of the same individual were marked at the same time with a sharp pencil. The measurements were made by one author (KH) with a sharp-pointed vernier calliper and read to the nearest tenth of a millimetre. The method of measuring has been presented by Berg (1983). Two separate measurements were obtained on different days. A difference of 0.5 mm or less was accepted. If the difference exceeded 0.5 mm, a third measurement was made. If the difference between the third measurement and one of the two earlier measurements was 0.5 mm or less, the two measurements were accepted. If the third measurement exceeded the range of accuracy of 0.5 mm to any of the two earlier measurements, the most extreme of the three measurements was excluded. The mean value of the two measurements thus obtained was used as the basis for further analysis.

Statistics

Pearson's correlation coefficient was used to express the degree of association between longitudinal changes in some continuous variables. The two-tailed *T*-test was used to test the significance of correlations. *P* values equal to or less than 0.05 were considered statistically significant.

Results

Table 1 shows the means and standard deviations of the arch width measurements at the canines, premolars, and first molars and also overjet and overbite at the ages of 7, 10, 12, 15, and 32 years in both genders. Longitudinal changes in the width dimensions, overjet, and overbite between the age levels are presented in Table 2. In all the dimensions, individual variation in the direction and magnitude of changes was wide at each age interval (Table 3).

Width at the canines

Maxillary canine width measured at the cusp tips increased markedly from 7 to 12 years of age in boys and somewhat less in girls. The increase continued up to the age of 15. From 7 to 15 years, the increase was greater in boys than in girls. Between 15 and 32 years of age, maxillary intercanine width measured at the cusp tips decreased in both genders (Table 2). The total change from 7 to 32 years of age was an increase, twice as great in males as in females.

In the mandible, there was an increase in canine width measured at the cusp tips in boys up to age 12 (mean 1.18 mm, range 1.7- > -2.34 mm) and in girls up to age 10 (mean 0.29 mm, range 4.3- > -3.27 mm). Thereafter, the canine widths continuously decreased. On average, the total change between ages 7 and 32 was an increase in males (0.59 mm) and a decrease in females (−0.32 mm; Table 2). At the gingival level, a decrease in intercanine width from age 15 to 32 occurred in both genders and both arches and was about twice as large in males as in females. The decrease at the gingival level was greater than at the cusp tips. Figure 1 shows individual variation in the development of the mandibular anterior width from adolescence to adulthood.

In boys, the change in maxillary canine width from 7 to 15 years of age was associated with the change in molar width of the same jaw (r = 0.674, P = 0.008) and with the change in mandibular canine width (r = 0.545, P = 0.036).

Table 1 Width dimensions of dental arches, overjet, and overbite at five ages. SD, standard deviation.

	7 years			10 years			12 years			15 years			32 years		
	N	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
	Girls														
Maxillary canine															
Cusp tips*	18	32.51	1.16	15	33.52	1.57	17	33.73	1.50	18	34.16	1.52	18	33.88	1.33
Gingival**	18	25.63	1.45	10	26.32	1.41	16	24.96	1.26	18	24.95	1.35	18	24.54	1.43
Maxillary first premolar*	17	31.25	1.62	16	31.83	1.93	18	31.04	1.87	18	30.99	1.82	18	30.81	1.85
Maxillary second premolar*	16	35.34	2.32	16	35.95	2.26	18	36.32	2.59	18	35.92	2.76	18	35.67	2.66
Maxillary first molar															
Mesiolingual cusp*	17	39.87	1.9	17	40.72	2.56	18	41.14	2.97	18	40.94	3.06	18	40.24	2.64
Distolingual cusp*	17	40.97	1.95	17	42.29	2.33	18	42.79	2.95	18	42.41	2.95	18	41.98	2.61
Gingival***	17	32.96	1.5	17	33.95	2.03	18	34.70	2.54	18	34.78	2.67	18	34.72	2.52
Mandibular canine															
Cusp tips*	16	25.42	0.98	15	25.29	1.05	18	25.35	1.40	18	25.1	1.52	18	24.98	1.58
Gingival**	16	20.30	0.92	13	19.56	1.35	18	19.27	1.55	18	18.77	1.39	18	18.46	1.45
Mandibular first premolar*	18	26.54	1.25	13	27.17	1.66	18	27.48	1.86	18	27.34	1.90	18	27.01	1.76
Mandibular second premolar*	16	29.92	1.9	15	30.51	2.08	17	30.48	2.73	18	30.43	2.43	17	29.75	2.30
Mandibular first molar															
Mesiolingual cusp*	18	33.77	2.13	17	34.34	2.58	18	34.27	2.85	18	33.93	2.92	18	33.4	2.74
Distolingual cusp*	18	35.80	1.87	17	36.65	2.49	18	36.78	2.87	18	36.67	2.86	18	36.28	2.50
Gingival***	18	31.67	2.04	17	32.14	2.63	18	32.17	2.81	18	31.89	2.83	18	31.42	2.61
Overjet****	15	2.90	1.21	17	3.33	1.13	18	3.28	0.89	18	2.85	0.87	18	2.58	0.73
Overbite****	15	2.63	1.53	17	3.20	0.92	18	3.42	0.94	18	3.24	1.17	18	2.97	1.31
	Boys														
Maxillary canine															
Cusp tips*	15	32.49	1.97	13	33.89	1.09	13	35.76	1.78	15	35.85	1.59	15	35.41	1.86
Gingival**	15	25.70	2.28	10	26.26	2.06	13	26.02	1.64	15	25.66	1.87	15	24.91	2.13
Maxillary first premolar*	15	31.42	1.93	13	31.67	2.20	15	31.44	2.04	15	31.68	2.26	15	31.04	2.44
Maxillary second premolar*	15	35.93	1.89	13	36.22	1.80	15	36.67	2.20	15	36.70	2.47	15	35.91	3.05
Maxillary first molar															
Mesiolingual cusp*	14	40.26	1.65	14	41.10	1.56	15	41.71	1.89	15	41.89	2.27	15	41.03	2.65
Distolingual cusp*	14	41.80	1.67	14	42.94	1.60	15	43.09	1.73	15	43.41	2.00	15	42.99	2.70
Gingival***	14	32.96	1.82	14	33.76	1.48	15	34.72	1.62	15	35.37	1.85	15	35.31	2.43
Mandibular canine															
Cusp tips*	15	25.21	2.23	14	26.21	2.34	15	26.38	1.50	15	26.08	1.81	15	25.8	2.17
Gingival**	15	20.35	1.62	9	20.53	1.74	14	20.07	1.52	15	19.56	1.64	15	18.86	1.97
Mandibular first premolar*	14	26.65	1.79	11	27.32	2.04	14	28.12	1.70	15	28.15	1.89	15	27.54	2.22
Mandibular second premolar*	13	30.59	1.50	11	30.94	1.48	14	31.62	1.52	15	31.42	2.16	15	30.30	2.68
Mandibular first molar															
Mesiolingual cusp*	15	34.40	1.53	14	34.78	1.27	15	34.74	1.63	15	34.65	2.11	15	34.11	2.91
Distolingual cusp*	15	36.63	1.36	14	37.21	1.42	15	37.62	1.73	15	37.76	2.45	15	37.37	3.08
Gingival***	15	32.29	1.45	14	32.67	1.37	15	32.53	1.73	15	32.38	2.23	15	31.92	3.02
Overjet****	12	3.33	1.00	14	3.45	0.80	15	3.23	0.78	15	2.87	0.64	15	2.67	0.79
Overbite****	12	2.85	1.16	14	2.86	1.23	15	3.20	0.96	15	3.03	0.97	15	2.59	1.20

Longitudinal measurements (mm) of 18 Finnish girls and 15 boys with normal Class I occlusions.
*Width between cusp tips.
**Width measured between intersections of the long axes of deciduous or permanent canines and the gingival margin. Measured only when canines fully erupted.
***Width measured between first molars at the gingival margin by the mesiolingual cusp.
****Measured only when crowns of first molars fully erupted.

Also from 15 to 32 years of age, the change in maxillary canine width in males was associated with the change in maxillary molar width (r = 0.535, P = 0.04) and with the change in mandibular canine width (r = 0.783, P = 0.001).

In girls, an association existed between the change in maxillary canine width and the change in mandibular canine width (r = 0.650, P =0.006) and also the change in mandibular molar width (r = 0.488, P = 0.040) from age 7 to 15. Between 15 and 32 years of age, the changes in maxillary and mandibular canine widths in females were associated only with changes in molar widths of the same jaw (r = 0.479, P = 0.05 in the maxilla and r = 0.595, P = 0.01 in the mandible).

Width at the first molars

The means of maxillary widths measured at the mesiolingual cusp tips, the distolingual cusp tips, and the gingival level increased from 7 to 32 years, the increase being greatest at the gingival level. The increase was greater distolingually

Table 2 Longitudinal changes with age in widths of dental arches, overjet, and overbite (mm) in a series of Finns with normal occlusions. SD, standard deviation.

	7–10 years			10–12 years			12–15 years			15–32 years			7–15 years			10–15 years			7–32 years		
	N	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
	Girls																				
Maxilla Canine																					
Cusp tips*	15	**1.05**	0.82	15	**0.32**	1.14	17	**0.25**	0.62	18	**−0.28**	0.38	18	**1.66**	1.57	15	0.46	1.18	18	1.37	1.50
Gingival**	10	0.14	1.38	10	−1.12	0.88	16	−0.27	0.54	18	**−0.41**	0.62	18	−0.69	1.37	10	−1.50	0.90	18	−1.09	1.22
First molar																					
Mesiolingual***	16	0.88	1.05	17	0.45	0.77	18	−0.20	0.42	18	**−0.70**	0.94	17	**1.07**	1.63	17	0.25	0.88	17	0.33	1.35
Distolingual****	16	1.54	1.09	17	0.48	1.02	18	−0.38	0.52	18	**−0.43**	0.78	17	**1.58**	1.70	17	0.10	1.18	17	1.11	1.60
Gingival*****	16	1.14	0.94	17	0.74	0.88	18	0.08	0.38	18	**−0.05**	0.75	17	**1.91**	1.78	17	0.83	1.03	17	1.84	1.79
Mandible Canine																					
Cusp tips*	13	**0.29**	1.09	15	**−0.15**	0.87	18	**−0.25**	0.47	18	**−0.12**	0.65	16	−0.19	1.37	15	−0.49	0.95	16	−0.32	1.27
Gingival**	11	−0.16	1.30	13	−0.76	0.89	18	−0.50	0.44	18	**−0.31**	0.54	16	−1.27	1.18	13	−1.16	0.92	16	−1.57	1.15
First molar																					
Mesiolingual***	17	0.62	0.82	17	−0.09	0.77	18	−0.33	0.54	18	**−0.54**	1.06	18	**0.16**	1.42	17	−0.42	0.9	18	−0.38	1.66
Distolingual****	17	0.79	1.05	17	0.18	0.79	18	−0.11	0.52	18	**−0.39**	0.89	18	**0.87**	1.68	17	0.05	0.92	18	0.48	1.74
Gingival*****	17	0.47	0.86	17	0.06	0.64	18	−0.28	0.50	18	**−0.48**	0.87	18	**0.22**	1.34	17	−0.25	0.86	18	−0.26	1.50
Overjet******	15	0.45	0.59	17	−0.05	0.55	18	−0.43	0.45	18	−0.27	0.42	15	−0.06	1.06	17	−0.48	0.76	15	−0.40	1.22
Overbite******	15	0.52	0.84	17	0.25	0.36	18	−0.18	0.59	18	−0.27	0.56	15	0.66	0.96	17	0.11	0.57	15	0.38	1.13
	Boys																				
Maxilla Canine																					
Cusp tips*	13	**1.59**	1.26	11	**1.41**	1.77	13	**0.37**	0.82	15	**−0.43**	0.74	15	3.36	1.93	13	1.81	1.43	15	2.93	2.08
Gingival**	10*	0.90	1.09	8	−0.30	1.51	13	−0.25	0.69	15	**−0.74**	0.74	15	−0.04	1.67	10	−0.76	1.17	15	−0.79	1.86
First molar																					
Mesiolingual***	13	1.04	0.71	14	0.46	1.30	15	0.18	0.73	15	**−0.86**	0.93	14	**1.56**	2.04	14	0.65	1.84	14	0.66	2.40
Distolingual****	13	1.26	0.96	14	0.08	1.47	15	0.32	0.75	15	**−0.42**	1.26	14	**1.53**	2.22	14	0.43	1.86	14	1.14	2.79
Gingival*****	13	0.98	1.00	13	0.81	1.11	15	0.65	0.77	15	**−0.05**	0.90	14	**2.44**	2.27	14	1.52	1.70	14	2.38	2.61
Mandible Canine																					
Cusp tips*	14	**1.12**	1.26	14	**0.06**	1.84	15	**−0.30**	0.52	15	**−0.28**	1.03	15	0.87	2.15	14	−0.2	2.10	15	0.59	2.31
Gingival**	9	0.37	1.3	8	−0.32	0.87	14	−0.50	0.46	15	**−0.71**	0.58	15	−0.78	1.13	9	−1.02	0.92	15	−1.49	1.24
First molar																					
Mesiolingual***	14	0.38	0.79	14	−0.04	1.04	15	−0.09	0.84	15	**−0.54**	1.20	15	**0.25**	1.69	14	−0.03	1.27	15	−0.29	2.29
Distolingual****	14	0.69	0.68	14	0.29	0.82	15	0.14	1.05	15	**−0.38**	1.17	15	**1.12**	1.83	14	0.45	1.76	15	0.74	2.46
Gingival*****	14	0.39	0.74	14	−0.10	0.80	15	−0.15	0.71	15	**−0.46**	1.09	15	**0.09**	1.68	14	−0.2	1.39	15	−0.37	2.32
Overjet******	11	0.35	0.91	14	−0.19	0.43	15	−0.36	0.50	15	−0.19	0.50	12	−0.31	1.11	14	−0.51	0.59	12	−0.58	1.15
Overbite******	12	0.21	0.70	14	0.26	0.57	15	−0.17	0.37	15	−0.45	0.80	12	0.12	0.77	14	0.12	0.56	12	−0.38	1.03

Bold text highlights changes of particular interest.
*Width measured between cusp tips of deciduous or permanent canines.
**Width measured between intersections of the long axes of deciduous or permanent canines and the gingival margin. Measured only when canines fully erupted.
***Width measured between mesiolingual cusps of first molars.
****Width measured between distolingual cusps of first molars.
*****Width measured between first molars at the gingival margin by the mesiolingual cusp tip.
******Measured when crowns of central incisors fully erupted.

Table 3 Distribution of subjects with normal Class I occlusion by type of change in dental arch width, overjet, and overbite between four age levels.

Dimension	Gender	7–15 years				10–15 years				12–15 years				15–32 years			
		Change			Range (mm)	Change			Range (mm)	Change			Range (mm)	Change			Range (mm)
		Increase	No change	Decrease		Increase	No change	Decrease		Increase	No change	Decrease		Increase	No change	Decrease	
Width at maxillary canines*	Female	16	0	2	4.50 -> -1.49	10	0	5	2.55 -> -1.76	12	0	5	1.74 -> -1.03	4	0	14	0.30 ->-1.02
	Male	14	0	1	6.72 -> -1.29	12	0	1	4.66 -> -0.52	10	0	3	2.14 -> -1.24	3	1	11	1.23 -> -1.30
Width at mandibular canines*	Female	8	1	7	2.27 -> -2.30	3	1	11	1.55 -> -2.69	5	0	13	0.86 -> -0.90	6	1	11	1.01 -> -1.31
	Male	10	0	5	4.72 -> -2.68	6	0	8	3.90 -> -3.43	5	1	9	0.65 -> -1.27	5	0	10	2.08 -> -1.99
Width at maxillary molars**	Female	13	0	4	4.41 -> -1.38	9	0	8	1.32 -> -1.11	6	0	12	0.52 -> -1.17	3	0	15	1.19 -> -2.63
	Male	11	0	3	4.75 -> -2.68	8	0	6	3.43 -> -3.60	8	1	6	1.30 -> -1.34	1	0	14	0.76 -> -2.50
Width at mandibular molars**	Female	6	0	12	3.73 -> -1.52	5	0	12	1.32 -> -1.81	5	1	12	1.32 -> -1.32	4	0	14	1.69 -> -2.67
	Male	8	0	7	2.50 -> -2.46	7	0	7	2.34 -> -3.07	7	1	7	1.63 -> -1.50	5	0	10	1.87 -> -2.30
Overjet***	Female	6	0	9	2.67 -> -2.41	4	0	13	1.02 -> -2.33	2	0	16	0.32 -> -1.47	5	0	13	0.33 -> -1.19
	Male	4	0	8	1.36 -> -2.10	5	0	9	0.30 -> -1.47	4	0	11	0.38 -> -1.41	5	0	10	0.69 -> -1.18
Overbite***	Female	12	0	3	2.28 -> -1.21	10	0	7	1.49 -> -0.73	6	0	12	1.00 -> -0.98	4	1	13	0.77 -> -1.81
	Male	6	0	6	1.65 -> -1.17	8	1	5	1.05 -> -0.96	6	0	9	0.41 -> -0.69	5	0	10	1.08 -> -1.98

*Width measured between cusp tips of deciduous or permanent canines.
**Width measured between mesiolingual cusp tips of first molars.
***Measured when crowns of central incisors fully erupted.

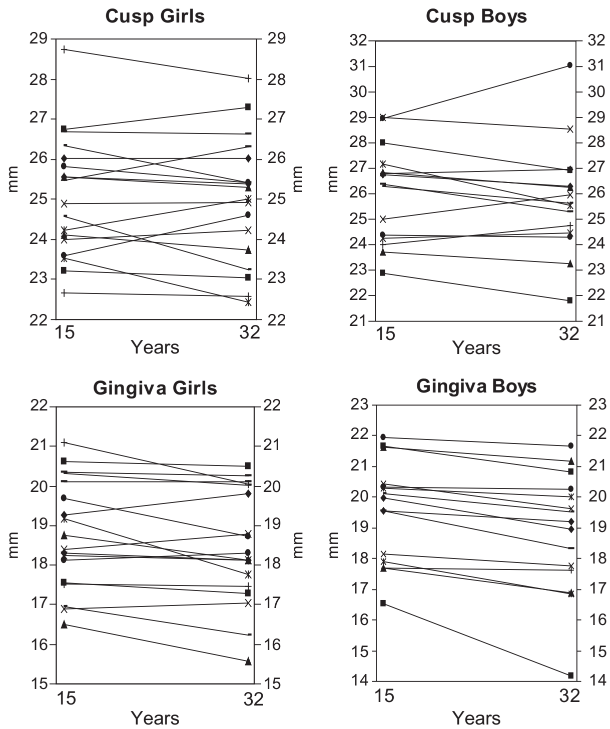

Figure 1 Width at mandibular canines from 15 to 32 years of age measured between cusp tips and at the gingival level in 18 girls and 15 boys.

than mesiolingually. In contrast to the maxilla, in the mandible only, the width at the distolingual cusps was larger at age 32 than at age 7, whereas the widths between the mesiolingual cusp tips and gingivally were smaller. In both jaws, all increases in average width dimensions occurred between 7 and 15 years of age. From 15 to 32 years of age, all dimensions decreased (Table 2, Figure 2).

Overjet and overbite

Overjet increased between 7 and 10 years of age. Then, there was a continuous decrease up to the age of 32, the decrease being greatest between 12 and 15 years. The total change from 7 to 32 years of age was a decrease, −0.40 mm (range 2.44 - > -3.43 mm) in females and −0.58 mm (range 1.29 - > -3.05 mm) in males (Table 2). No associations were found between changes in overjet and changes in arch widths during any age interval.

On average, overbite increased in females from 7 to 32 years of age (mean 0.38 mm, range 2.12 - > -2.06 mm) and decreased in males (mean −0.38 mm, range 0.7 - > -2.54 mm). Increase in overbite occurred between 7 and 12 years of age in both genders. From 12 to 32 years, overbite decreased, the greatest decrease being between 15 and 32 years (Table 2). In females, the change in overbite from 15 to 32 year of age was negatively correlated with the change in the mandibular

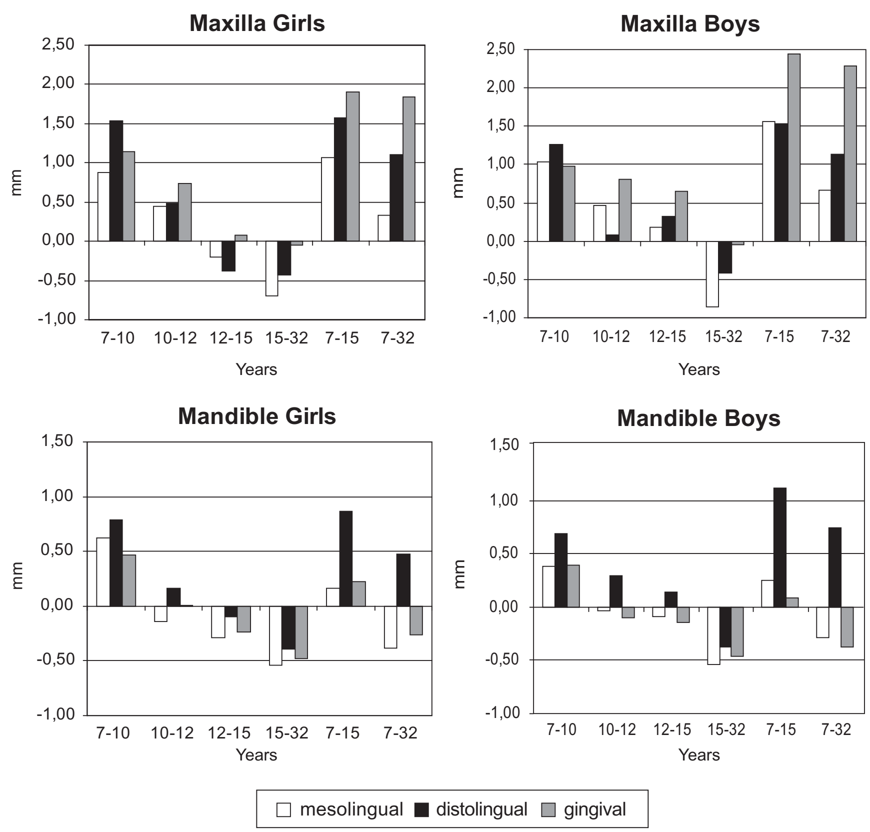

Figure 2 Means of changes in arch widths at first molars measured between mesiolingual cusp tips, distolingual cusp tips, and gingivally

intercanine distance measured at the cusp tips ($r = -0.495$, $P = 0.04$) and the change in mandibular intermolar width ($r = -0.599$, $P = 0.01$). No similar associations were found in males.

Discussion

Our longitudinal findings of changes in the width of the dental arches highlight the changes that occur in young adults with normal and untreated occlusion. The results show that both dental arches are slightly narrowed in adulthood. The means of the changes are mostly very small in the order of 0.5 to a few millimetres. Changes in overjet and overbite are also seen and they are likewise within the range of plus or minus a few millimetres. The width measurements at the gingival level and at the cusp tips of the first molars clearly show that the molars become mesially rotated and uprighted during late occlusal development.

Comparing the results of the present study with dental arch dimensions presented in earlier studies is difficult because of the differences in sample selections, different reference points, and measuring techniques. However, the arch width measurements reported by Huggare *et al.* (1993) for 9-year-old Finnish children are very similar to those found in this study for 10-year-olds. In contrast, the width dimensions of the present group of Finns were mostly larger than those reported for Americans (Moorrees, 1959; Moyers *et al.*, 1976; Bishara *et al.*, 1997). The intercanine distances of our Finnish group were also larger than those of Norwegians (Berg, 1983).

Finnish intermolar widths measured at the gingival level correspond to those of Norwegian and American children (Berg, 1983; Spillane and McNamara, 1989) with normal occlusion. Howe *et al.* (1983) suggest a transpalatal width of 35–39 mm as the lower limit that is adequate for accommodation of permanent dentition with near ideal occlusion. In the present normal occlusion sample, the transpalatal arch width was 34.7 mm for females and 35.3 mm for males at the age of 32.

Chronological age was used as a parameter in defining the changes in arch dimensions. At the age of 7 years, all the measured teeth except first molars were deciduous teeth, but during the transitional period, marked variation was found in the stage of dental development and especially in the phase of canine eruption within each age level. For this reason, associations between the changes were studied only between 7 and 15 years and between 15 and 32 years.

Changes in canine width

In our study, maxillary intercanine width measured at the cusp tips increased up to the age of 15 and decreased thereafter. Similarly, maxillary intercanine width in Americans of Caucasian origin increased until 13 years of age (Sillman 1964; Bishara *et al.*, 1997), until 15 years of age in Turkish children (Arslan *et al.*, 2007), and up to the age of 16 in Swedes (Thilander 2009). Maxillary intercanine width has been reported to decrease after full eruption of the permanent teeth (Bishara *et al.*, 1997; Carter and McNamara 1998).

The current findings, with the increase in mandibular intercanine width at the cusp tips up to 10 years of age, support the observations of Bishara *et al.* (1997) and Knott (1972) that for most individuals, an increase in this dimension occurs largely before the eruption of the permanent canines. Mandibular intercanine width decreased progressively from 10 to 32 years in Finnish girls and from 12 to 32 years in boys (Table 2). Similar decreases from the mixed dentition stage to adulthood have been found in earlier studies (Sinclair and Little, 1983; Bishara *et al.*, 1994; Carter and McNamara, 1998; Thilander, 2009). Tibana *et al.* (2004) found a small but significant reduction in lower intercanine width between 21 and 28 years of age.

In the present subjects with normal occlusions and no crowding at age 15, gingival arch width at the canines diminished in both genders from age 15 to 32, an approximately equal amount in both arches, but more in males than in females.

Changes at the first molars

Maxillary intermolar widths at the cusp tips increased up to the age of 12 in girls and up to age 15 in boys. A similar increase up to the adolescent years has been shown in earlier studies (Moorrees, 1959; Sillman, 1964; Bishara *et al.*, 1997; Thilander 2009). Transpalatal width measured at the gingival margin increased from 7 to 15 years corresponding to earlier findings (Spillane and McNamara, 1989; Hesby *et al.*, 2006).

Lateral growth of the jawbones is known to continue up to 17 years of age and to be greater posteriorly (Björk and Skieller, 1977). Thus, the present material, with the data point at age 15, is not ideal for interpreting longitudinal changes in young adulthood especially in males. Growth of the maxillary and mandibular basal structures near the first molars has been found to be differential (Hesby *et al.*, 2006). The maxillary basal structures move laterally as the suture widens, whereas the mandibular basal bone at the first molars does not widen substantially thus limiting lateral drift of the first molars. This agrees with our finding that maxillary intermolar width at the gingival level increased about 2 mm between 7 and 15 years of age, while in the mandible, the increase was only 0.1–0.2 mm. In spite of the differential growth of the maxillary and mandibular basal structures near the first molars, a good Class I molar relationship remained unchanged. It is possible to maintain a stable occlusion because the molars adapt to growth changes by means of rotations and altering inclinations. This is clearly shown in the present study, where differences in age changes in intermolar widths at the mesiolingual and distolingual cusps and at the gingival level indicate mesiolingual rotation of the first molars in both jaws and uprighting of the maxillary first molars. Uprighting of the maxillary first molars with increasing age has been reported also by Marshall *et al.* (2003), but to our knowledge, there are no previous longitudinal studies on rotations of the first molars and changes in their transversal inclinations in the same individuals.

In the maxilla, our Finnish sample with normal occlusions showed a decrease in intermolar widths from age 15 to 32, the decrease being greatest at the mesiolingual cusps and minimal at the gingival level. Previous reports on growth changes from adolescence to adulthood have been conflicting, showing a decrease (Sinclair and Little, 1983; Carter and McNamara, 1998), an increase (Harris, 1997; Bondevik, 1998; Marshall *et al.*, 2003), or no change (Sillman, 1964; Henrikson *et al.*, 2001). Some studies reported decreases in intermolar width in adulthood particularly in females (Sinclair and Little, 1983; Bishara *et al.*, 1997; Carter and McNamara, 1998), while others found no change (Tibana *et al.*, 2004).

Mandibular intermolar distances started to decrease earlier than maxillary distances. The total decrease at the mesiolingual cusps and at the gingival level up to the age of 32 was nearly the same but smaller at the distolingual cusps. Similarly, decreasing mandibular intermolar width dimensions with increasing age have been observed previously (Carter and McNamara, 1998; Tibana *et al.*, 2004), but also an increase in both genders between 10 and 15 years (Arslan *et al.*, 2007) and an increase in males and no change in females have been reported (Henrikson *et al.*, 2001).

The present study indicates that both dental arches are slightly narrowed from adolescence to adulthood. This is in accordance with the statement by Bishara *et al.* (1997) that after the eruption of permanent dentition, the clinician should either expect no changes or a minimal decrease in arch width. A small, but not clinically insignificant, decrement in most adult dental arch dimensions was also found by Carter and McNamara (1998).

Overjet and overbite

In the present Finnish group, overjet increased between 7 and 10 years of age and then started to decrease. This is in accord with an earlier finding on an untreated normal sample (Sinclair and Little, 1983). During adulthood, decreases or no changes in overjet have been demonstrated in several studies paralleling our results (Forsberg, 1979; Harris, 1997; Bondevik, 1998; Carter and McNamara, 1998; Tibana *et al.*, 2004; Thilander, 2009).

The changes in overbite followed the same pattern as in overjet: an increase in the early years of transition changed to a decrease towards adolescence and adulthood corresponding to the findings of Moorrees (1959) and Sinclair and Little (1983), whereas Carter and McNamara (1998) and Harris (1997) have reported overbite to be stable during adulthood. From 15 to 32 years of age, overbite in Finns decreased more frequently than increased, and in accord with earlier observations, the decrease was greater on average in males than in females (Humerfelt and Slagsvold, 1972; Bishara *et al.*, 1984; Bondevik 1998). Many Finns demonstrated incisal attrition at 32 years of age. Attrition of the teeth with increasing age is normal and obviously affects the development of overbite and overjet in the adult years.

Concluding remarks

In planning orthodontic treatment procedures, it is necessary to know the normal changes that occur in arch dimensions during growth. The average changes, indicated in several studies, have been used as guidelines in orthodontic treatment planning. Corresponding longitudinal studies have not been made previously in Finnish children with normal occlusions. We expect the present findings to help clinicians in following up occlusal development and in estimating optimal timing of orthodontic treatment. However, the means are applicable to the average child, not to an individual. The variability in age changes was considerable. For each variable in each gender, some subjects showed increases, while others showed decreases during each age interval. Thus, accurate prediction of future development cannot be made on an individual level in young children, but the clinician must see and respond to continuous alterations.

Funding

Finnish Dental Society; Orthodontic Section of the Finnish Dental Society; Finnish Women Dentist’s Association.

Acknowledgements

Warm thanks to Mr Ahti Niinimaa for his professional assistance with the statistics. We also want to thank Mr Timo Päivärinta for helping us with the pictures. We owe special thanks to all those who kindly helped us during the sample collection.

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