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Timing of Demirjian's tooth formation stages

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Abstract

Background: Global differences in Demirjian et al.'s method of assessing dental maturity are thought to be due to population differences.

Aim: The aim of this study was to investigate the timing of individual tooth formation stages in children from eight countries.

Research design: This was a meta-analysis of previously published data from retrospective cross-sectional studies of dental maturity.

Method: Data of mandibular permanent developing teeth from panoramic radiographs (Demirjian's stages) were combined from Australia, Belgium, Canada, England, Finland, France, South Korea and Sweden ($n = 9002$, ages 2–16.99 years). Age-of-attainment was calculated using logistic regression for each group by sex and meta-analysis of the total. Overlapping 95% confidence intervals of the means was interpreted as no significant difference.

Results: Mean ages for each group and total were significantly different in 65 out of 509 comparisons ($p < 0.05$). Some of these were of small sample size but there was no consistent pattern. Apex closure of the first molar was significantly later in children from Quebec and this might explain differences found in the dental maturity score.

Conclusions: These results suggest no major differences in the timing of tooth formation stages between these children. This fails to explain previous findings of differences using Demirjian's dental maturity method.

Keywords: *Demirjian's tooth stages, permanent tooth formation, panoramic radiographs*

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Introduction

The most widely used dental maturity method is that described by Demirjian et al. (Demirjian et al. 1973, 1993–1994; Demirjian and Goldstein 1976) and is based on a large, random study of Canadian children. Formation of seven mandibular permanent teeth is assessed and dental age calculated and compared to chronological age. Numerous worldwide groups appear to be dentally advanced compared to the standard and this has been attributed to population differences and/or a secular trend. The aim of this study was to investigate the possibility of population differences in the timing of individual mandibular tooth formation stages in children from Australia, Belgium, Canada, England, Finland, France, South Korea and Sweden.

Materials and methods

A dental maturity database was collected by the second author from published studies from Helsinki, Turku and Kuhmo, Finland (Nyström et al. 1986, 1988; Kataja et al. 1989), London, England (Liversidge et al. 1999), Leuven, Belgium (Willems et al. 2001), various parts of Sweden and Kwangju, South Korea (Teivens and Mörnstad 2001), Adelaide, South Australia (McKenna et al. 2002), and Montreal, Quebec and southern France (Chaillet and Demirjian 2004). Dental maturity curves have recently been described for this database (Chaillet et al. 2005). Apart from the Korean group, most other children were of European origin, although 10% of the Australian group was not Australian born and 50% of the English group was of Bangladeshi origin. Data from 9002 children aged 2–16.99 years were included in this study. Age and sex distribution for each group is shown in Figure 1. Mandibular teeth (excluding third molars) were scored in stages described by Demirjian, Goldstein and Tanner (1973), Demirjian and Goldstein (1976) and/or using the CD-ROM program (Demirjian 1993–1994). No tests of inter-observer reproducibility were available, but no significant differences were reported for intra-observer reproducibility; percentage agreement ranged from 87% to 93% with Kappa over 0.9 from some of the source references.

Mean age-of-attainment and standard error was calculated by logistic regression for tooth stages for each group, boys and girls separately (256 and 253 calculations for girls and boys, respectively). Data from eight (or fewer) groups were combined in a meta-analyses for each tooth stage giving overall mean age-of-attainment and standard error. The overall mean age-of-attainment was calculated using a weighting factor inversely proportional to the variance of the mean. In 83 instances groups were omitted from the meta-analysis because of the difference in age range and uneven age distribution between the eight groups. For example, groups from Australia, France and Quebec include very few children younger than age 6. The age range for the study from England was 4–9 years and analyses for stages that occur after this age exclude this group. Groups were also excluded if more than 50% of children in the group had reached the stage in the youngest age cohort, taken as one tenth of a year. For example, in the analysis of M_1 (tooth notation given in the Appendix) stage E (root furcation), all the boys from Quebec had reached or surpassed this stage and this group was excluded from the overall mean in boys for this stage. Considerable heterogeneity was noted between groups. Mean age was compared with overall mean for each group separately, and overlapping 95% confidence intervals was interpreted as no significant difference.

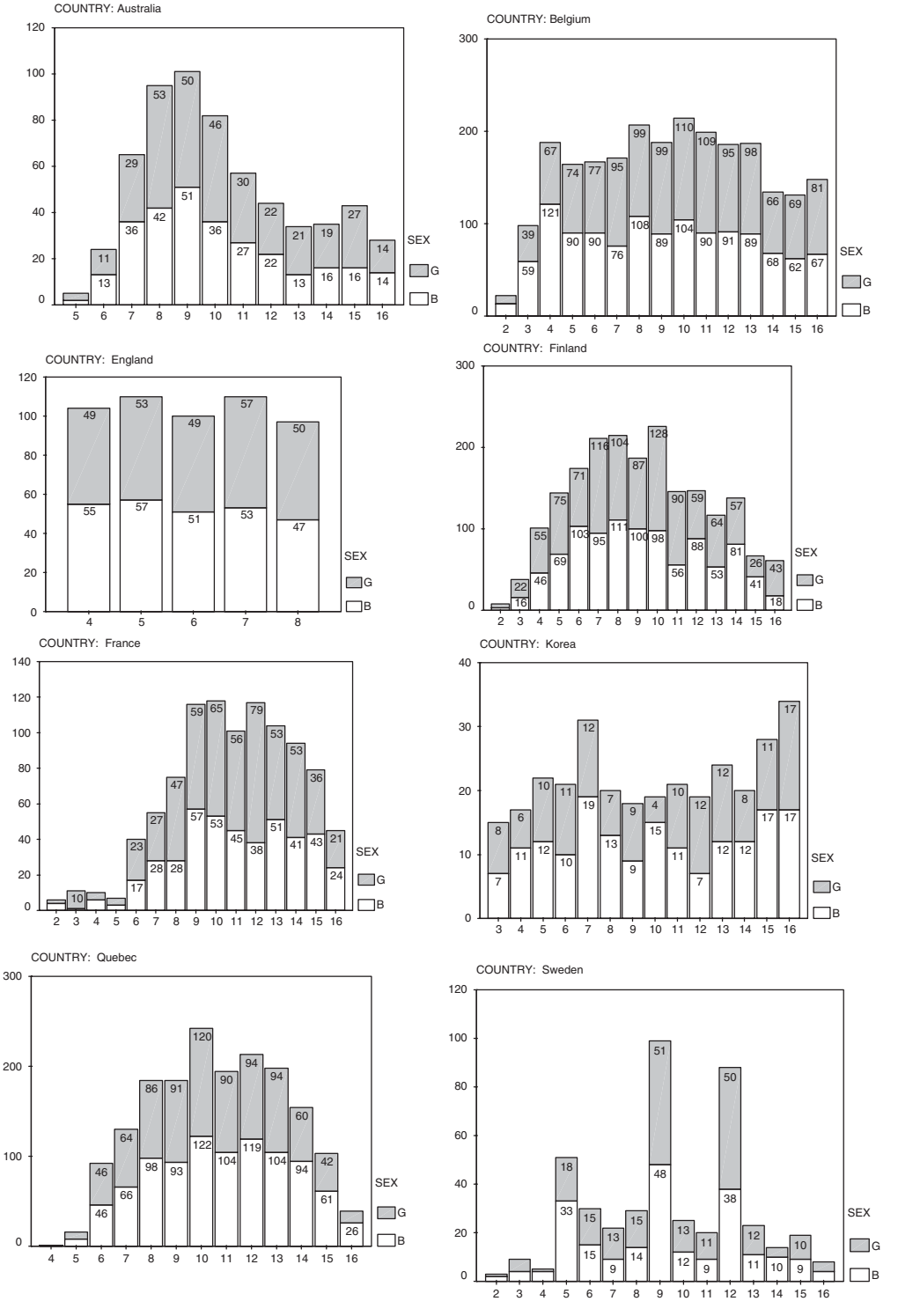

Figure 1. Age and sex distribution for each group by country. *X*-axis is age groups in years, 3 indicates all children aged 3 years, etc.

The mean age of children 'in a stage' was also calculated for girls, boys and combined sexes. Stage H (mature apex) was excluded as this would represent the age distribution and not the parameter of growth.

Results

Mean age-of-attainment for mandibular tooth formation stages for the each group and the combined groups are shown in Tables I–IX.

In 444 of 509 calculations, no significant differences were noted between each group and overall mean age. One example (M_2 stage H) is shown in Figure 2. Mean age of girls from Australia and Belgium are earlier than other groups, however this pattern is

Table I. Mean age (standard error) of dental formation stages in children from Adelaide, South Australia (McKenna et al. 2002). *n*, number of children in each stage, i.e. for I_1 stage F, 2 out of a total of 325 girls are in this stage.

		Girls			Boys		
Tooth	Stage	Mean	SE	*n*	Mean	SE	*n*
I_1	F	5.63	0.28	2			
	G	6.22*	0.13	22	6.72	0.11	36
	H	7.31*	0.14	298	7.75*	0.13	240
I_2	F	6.21	0.14	22	6.07	0.29	48
	G	7.31	0.13	39	7.92	0.13	34
	H	8.30*	0.11	259	8.75*	0.11	200
C	E	6.03	0.22	23	6.66	0.10	73
	F	7.23	0.16	129	8.74	0.10	105
	G	10.17	0.11	42	11.50	0.16	36
	H	11.23*	0.12	127	13.18	0.20	60
P_1	E	6.57	0.19	96	7.36	0.13	84
	F	9.17	0.10	76	9.42	0.09	78
	G	10.76	0.12	38	11.55	0.14	26
	H	12.01	0.15	105	12.85	0.19	66
P_2	D	5.64	0.44	41	5.88	0.42	70
	E	7.60	0.19	87	8.52*	0.12	70
	F	9.70	0.10	79	10.18	0.13	71
	G	11.75	0.15	31	12.75	0.19	20
	H	12.93	0.17	82	13.88	0.21	48
M_1	F	5.63	0.35	15	6.09	0.24	16
	G	6.83	0.21	93	7.02	0.12	97
	H	9.26	0.15	214	9.43*	0.13	170
M_2	D	5.55	0.49	73	6.90	0.17	68
	E	8.56	0.13	90	8.77	0.19	91
	F	10.56	0.12	51	11.04	0.14	40
	G	12.03	0.14	49	12.74	0.19	32
	H	14.17	0.18	55	14.62	0.20	36
Total *n*				325			288

* $p < 0.05$.

Table II. Mean age (standard error) of dental formation stages in children from Leuven, Belgium (Willems et al. 2001).

		Girls			Boys		
Tooth	Stage	Mean	SE	*n*	Mean	SE	*n*
I_1	E	4.49	0.11	86	4.61	0.08	147
	F	5.38	0.08	71	6.17	0.08	93
	G	6.75	0.08	107	7.22	0.08	119
	H	7.92	0.08	834	8.52	0.09	709
I_2	E	5.00	0.10	98	5.27	0.08	144
	F	6.39	0.08	96	6.83	0.08	114
	G	7.53	0.07	141	8.11	0.09	157
	H	8.94	0.08	732	9.76	0.09	591
C	E	6.39	0.08	106	6.94	0.09	129
	F	7.64	0.07	263	8.38	0.08	314
	G	10.22	0.07	178	11.68*	0.09	149
	H	11.96	0.10	422	13.39	0.09	260
P_1	C	3.09	0.21	116	3.60	0.11	205
	D	5.35	0.09	142	5.81	0.08	178
	E	7.20*	0.07	142	7.82*	0.08	123
	F	8.67*	0.06	230	9.14	0.08	263
	G	10.89	0.08	148	11.91*	0.09	98
	H	12.32	0.08	382	13.02	0.09	290
P_2	B	3.63	0.16	53	3.81	0.12	99
	C	4.70	0.10	115	5.00	0.08	149
	D	6.32	0.10	154	6.61	0.09	164
	E	8.09*	0.08	109	8.43*	0.09	126
	F	9.18	0.08	273	9.75	0.09	267
	G	11.80	0.08	157	12.63	0.10	113
	H	13.47	0.09	278	13.99	0.09	212
M_1	E	3.71	0.11	68	3.93	0.06	124
	F	4.87	0.08	127	5.14*	0.07	187
	G	6.62	0.08	230	7.17*	0.09	234
	H	9.05	0.08	721	9.68	0.10	598
M_2	A	3.08	0.19	18	3.34	0.12	39
	B	3.42	0.18	72	3.77	0.12	101
	C	4.83	0.10	107	4.95	0.09	170
	D	6.36	0.09	175	6.80	0.09	175
	E	8.38	0.07	152	8.73	0.08	161
	F	9.83	0.10	192	10.40	0.08	187
	G	11.66	0.08	249	12.42	0.09	194
	H	14.41	0.10	200	14.86	0.10	148
Total *n*				1188			1217

* $p < 0.05$

Table III. Mean age (standard error) of dental formation stages in children Montreal, Quebec (Chaillet and Demirjian 2004).

		Girls			Boys		
Tooth	Stage	Mean	SE	*n*	Mean	SE	*n*
I_1	F	5.38	0.42	39	4.75	0.63	54
	G	6.66	0.14	110	7.05	0.10	136
	H	8.40*	0.09	655	8.79	0.08	748
I_2	F	5.92	0.20	71	6.37	0.15	97
	G	7.48	0.09	132	7.97	0.08	158
	H	9.17	0.08	591	9.70	0.08	661
C	F	7.51	0.10	171	8.30*	0.08	209
	G	9.66	0.08	203	10.49*	0.08	282
	H	11.75	0.09	344	13.10	0.09	300
P_1	E	6.48	0.14	168	6.87	0.13	191
	F	8.99	0.08	179	9.34	0.08	214
	G	10.88	0.08	157	11.40	0.08	189
	H	12.52	0.09	272	13.17	0.09	293
P_2	E	7.50	0.11	174	7.69	0.12	214
	F	9.71	0.08	210	10.10	0.09	236
	G	11.87	0.09	130	12.32	0.09	177
	H	13.31	0.09	202	14.10	0.10	206
M_1	G	6.19	0.18	278	5.83*	0.34	340
	H	10.10*	0.09	504	10.72*	0.07	554
M_2	D	6.04	0.18	142	5.53*	0.35	161
	E	8.49	0.08	148	8.57	0.10	202
	F	10.16	0.07	118	10.69	0.14	121
	G	11.34	0.08	298	11.80*	0.08	342
	H	15.06	0.16	85	15.51	0.14	97
Total *n*				808			943

* $p < 0.05$.

not apparent for other stages of this tooth or other teeth. One curious result is the significant late timing of M_1 stage H in children from Quebec shown in Figure 3. The large confidence interval of the Korean group in this figure is probably due to the small number of 7- and 10-year-old girls in the sample. Significant differences ($p < 0.05$) were observed in 65 tooth/stage comparisons. Small sample size may partly explain this as many involve younger children. For example, Swedish girls were significantly later than the overall mean for stage E of M_1, however, the number of 3- and 4-year-olds was less than five for both sexes. Mean age of Swedish boys was not different to the overall mean for boys for this stage, but was slightly earlier than girls from this group.

For the combined groups (Table IX), girls are earlier than boys in all stages of tooth formation. These sex differences are small for earlier stages (0.03 year for M_2 stage A, initial mineralization) and large for later developing teeth, the maximum being late root stages of the canine (1.51 year for canine stage H). In 21/251 comparisons between the sexes the mean age for a group was earlier in boys than girls but sample size in almost all

Table IV. Mean age (standard error) of dental formation stages in children from London, England (Liversidge et al. 1999).

		Girls			Boys		
Tooth	Stage	Mean	SE	*n*	Mean	SE	*n*
I_1	E	4.23	0.12	53	3.84	0.27	85
	F	5.40	0.08	62	5.76	0.09	62
	G	6.62	0.08	49	6.98	0.10	45
	H	7.60	0.13	76	7.91	0.12	56
I_2	E	4.85	0.10	66	4.92	0.13	88
	F	6.19	0.09	65	6.71	0.09	52
	G	7.44	0.10	50	7.76	0.11	42
	H	8.76	0.24	32	8.79	0.15	21
C	E	6.15	0.11	60	6.88	0.10	73
	F	8.21*	0.14	101	8.76	0.01	88
P_1	C	3.75	0.30	65	4.03	0.16	86
	D	5.35	0.09	75	5.70	0.10	82
	E	6.83	0.09	83	7.32	0.09	69
	F	8.58*	0.18	31	8.87	0.18	15
P_2	C	5.02	0.11	71	5.15	0.09	79
	D	6.47	0.11	69	6.69	0.10	69
	E	7.85	0.12	51	8.12	0.12	44
M_1	E	3.96	0.20	64	4.16	0.16	76
	F	5.49	0.09	41	5.68	0.09	51
	G	6.31	0.24	119	6.69	0.08	106
M_2	C	4.92	0.08	96	4.91	0.07	123
	D	6.80	0.11	92	7.27*	0.10	70
	E				8.91	0.20	16
Total *n*				258			263

* $p < 0.05$.

of these was small. Descriptive statistics for children 'in a specific tooth formation stage' are shown in Table X.

Discussion

The most interesting result from this study is the lack of any consistent population difference in the timing of dental formation. Many of the significant differences relate to comparisons between small numbers, although the late timing of root maturation of the first molar in children from Quebec is inexplicable. The median age for this stage from the original sample is considerably earlier at 9.5 years for girls (Demirjian and Levesque 1980). Comparison of timing of individual tooth stages from the original study show that several stages in the present study are up to 1 year later (stages E for I_1, I_2 and canine and stages D and E of P_1), also seen in a group of Chinese children (Zhao et al. 1990). However, statistical analyses differ. Demirjian and Levesque (1980) calculated the median from the proportion of children in that stage, grouped into 6-monthly age groups, giving no measure

Table V. Mean age (standard error) of dental formation stages in children from Helsinki, Turku and Kuhmo, Finland (Nyström et al. 1986, 1988; Kataja et al. 1989).

		Girls			Boys		
Tooth	Stage	Mean	SE	*n*	Mean	SE	*n*
I_1	E	3.81*	0.12	115	4.07	0.13	127
	F	5.80	0.07	54	6.16	0.07	56
	G	6.53	0.07	98	6.77	0.06	126
	H	7.56	0.07	706	8.07	0.07	638
I_2	E	4.75	0.08	112	5.29	0.08	122
	F	6.35	0.07	58	6.78	0.06	72
	G	7.02	0.07	158	7.54	0.06	164
	H	8.57	0.07	602	9.16	0.07	527
C	E	5.74	0.07	151	6.50	0.08	196
	F	7.52	0.07	188	8.53	0.07	229
	G	9.35*	0.08	226	10.95	0.09	184
	H	11.60	0.08	297	13.38	0.10	178
P_1	C	3.49	0.10	91	3.47	0.17	98
	D	5.30	0.07	107	5.55	0.08	141
	E	6.72	0.07	178	7.15	0.07	181
	F	8.51*	0.06	178	8.97	0.07	189
	G	10.25*	0.08	166	11.00*	0.09	143
	H	11.98	0.09	264	12.86	0.10	214
P_2	B	3.83	0.17	44	3.63	0.23	48
	C	4.77	0.12	113	4.85	0.13	142
	D	6.43	0.09	102	6.79*	0.08	116
	E	7.55	0.08	161	8.01	0.08	157
	F	9.15	0.07	187	9.59	0.09	190
	G	11.20*	0.09	191	11.81	0.11	167
	H	13.58	0.17	165	14.14	0.11	129
M_1	E	3.61	0.10	87	4.00	0.08	90
	F	5.27	0.08	78	5.57	0.08	104
	G	6.34	0.08	285	6.77	0.07	313
	H	9.27	0.07	531	9.96	0.08	449
M_2	A	3.39	0.17	13	3.38	0.21	14
	B	3.80	0.15	48	3.97	0.13	38
	C	4.80	0.10	141	4.84	0.09	174
	D	6.76	0.08	155	7.02	0.07	165
	E	8.34	0.07	179	8.70	0.07	193
	F	10.10	0.22	138	10.71	0.09	116
	G	11.48	0.08	212	12.17	0.28	198
	H	14.88	0.13	96	15.36	0.13	67
Total *n*				1002			978

* $p < 0.05$.

of variance, whereas the present study uses logistic regression utilizing every child's chronological age.

Numerous studies of dental maturation using Demirjian's method (based on Tanner's bone age maturity) have shown an advancement compared to the standard (see Loevy 1983; Nykänen et al. 1998; Farah et al. 1999; Eid et al. 2002; Hedge and Sood 2002;

Table VI. Mean age (standard error) of dental formation stages in children from France (Chaillet and Demirjian 2004).

		Girls			Boys		
Tooth	Stage	Mean	SE	*n*	Mean	SE	*n*
I_1	E	4.17	0.26	2	4.31	0.30	9
	F	4.46*	0.21	24	5.66	0.29	16
	G	6.84	0.09	49	6.95	0.13	56
	H	8.27	0.11	452	8.82*	0.12	351
I_2	E	4.46	0.25	8	4.44	0.36	17
	F	5.88	0.22	19	6.50	0.18	17
	G	6.93	0.10	85	7.32	0.13	73
	H	9.07	0.10	413	9.45	0.09	324
C	E	5.25	0.27	20	6.01	0.22	42
	F	6.69*	0.15	128	7.85*	0.16	113
	G	9.81	0.08	114	10.56*	0.09	109
	H	11.65	0.10	260	12.98	0.08	157
P_1	C	3.73	0.27	10	3.95	0.12	7
	D	5.60	0.26	4	5.53	0.33	10
	E	5.92*	0.22	62	6.22*	0.23	75
	F	8.20*	0.12	132	9.03	0.10	100
	G	11.06	0.10	104	10.66	0.09	89
	H	12.30	0.10	218	13.06	0.10	153
P_2	B	3.59	0.26	8	3.75	0.39	5
	C	4.90	0.30	3	4.89	0.31	2
	D	5.60	0.26	10	5.53*	0.28	28
	E	6.00*	0.26	91	7.14*	0.18	76
	F	8.90*	0.12	150	9.44	0.11	122
	G	11.50	0.27	125	11.98	0.11	98
	H	13.69	0.14	144	14.16	0.11	103
M_1	E	4.12	0.22	3	4.16	0.23	8
	F	4.74	0.28	5	5.88	0.16	5
	G	6.03*	0.04	116	6.26*	0.10	129
	H	9.22	0.12	403	10.09	0.09	291
M_2	A				4.07	0.23	1
	B	3.88	0.26	2	4.32	0.28	7
	C	4.12*	0.22	8	5.19	0.38	11
	D	5.61	0.27	85	6.40	0.21	78
	E	8.63	0.11	80	9.11	0.12	64
	F	10.12	0.09	73	10.45	0.08	67
	G	11.31	0.09	218	11.89	0.11	151
	H	15.04	0.12	63	15.36	0.12	54
Total *n*				539			439

* $p < 0.05$.

Prabhakar et al. 2002; Liversidge 2003; Leurs et al. 2005). The reason for this is unclear and suggestions include population differences or a secular trend. Many of these comparative studies are of small samples size or age range with uneven age distribution. Differences in dental maturity measured in this way are complicated by the scoring matrix and may have little biological meaning (Prahl-Andersen et al. 1979). To date, few population differences

Table VII. Mean age (standard error) of dental formation stages in children from Kwangju, South Korea (Teivens and Mörnstad 2001). *n* indicates number of children in that stage.

		Girls			Boys		
Tooth	Stage	Mean	SE	*n*	Mean	SE	*n*
I_1	E	4.45	0.03	15	4.56	0.24	19
	F	6.40*	0.18	5	6.25	0.14	10
	G	6.86	0.15	16	7.01	0.15	21
	H	8.38	0.26	89	8.54	0.26	108
I_2	E	5.03	0.24	12	5.33	0.17	14
	F	6.56	0.02	15	6.49	0.16	17
	G	7.86	0.25	12	7.70	0.22	29
	H	9.12	0.20	82	9.94	0.20	90
C	E	5.91	0.19	26	6.25	0.13	42
	F	8.47*	0.24	15	9.39*	0.24	28
	G	10.30	0.27	17	11.60	0.20	19
	H	12.19	0.16	56	13.54	0.20	50
P_1	D	4.63	0.25	17	4.80*	0.16	26
	E	6.72	0.01	25	6.94	0.16	33
	F	9.09*	0.01	16	9.38	0.22	29
	G	11.31	0.20	14	11.75	0.22	15
	H	12.56	0.22	52	13.26	0.23	53
P_2	B	4.31	0.29	3	4.16	0.19	1
	C	4.69	0.32	7	4.29*	0.15	18
	D	5.65	0.22	18	5.86	0.16	22
	E	7.42	0.19	19	7.48	0.18	33
	F	9.36	0.20	23	10.02	0.24	31
	G	12.19	0.21	18	12.77	0.16	18
	H	13.93	0.25	38	14.33	0.23	40
M_1	E	4.01	0.31	11	3.89	0.26	20
	F	5.51	0.15	10	5.79	0.10	21
	G	6.62	0.22	24	7.34	0.18	28
	H	9.04	0.27	83	9.45	0.19	96
M_2	A	3.62	0.41	2	3.66	0.28	4
	B	4.01	0.31	7	4.18	0.17	11
	C	5.09	0.13	12	5.14	0.15	17
	D	6.45	0.20	27	6.58	0.15	34
	E	9.11	0.21	14	9.05	0.20	27
	F	10.92	0.28	16	11.21	0.20	19
	G	12.57*	0.20	26	13.10*	0.17	29
	H	15.11	0.18	26	15.41	0.17	26
Total *n*				137			172

* $p < 0.05$.

in the timing of tooth formation from radiographs have been demonstrated partly because of the large variance in the timing of stages necessitating a big sample and wide age range.

Demirjian's work remains the largest and only random study of mandibular permanent tooth formation (radiographs of 6000+ children, aged 2–25) (Demirjian and Levesque 1980; Levesque et al. 1981) but falls short of WHO guidelines of 200 per age group and sex

Table VIII. Mean age (standard error) of dental formation stages in children from Sweden (Teivens and Mörnstad 2001).

		Girls			Boys		
Tooth	Stage	Mean	SE	*n*	Mean	SE	*n*
I_1	E	4.66	0.24	20	4.73	0.20	33
	F	6.01	0.17	13	6.14	0.23	8
	G	7.11	0.18	11			
	H	7.81	0.16	170	8.32	0.17	141
I_2	E	4.94	0.22	23	5.59	0.10	19
	F	6.61	0.18	7	6.51	0.20	15
	G	7.31	0.16	28	7.93	0.17	31
	H	8.56	0.13	151	9.07	0.14	120
C	E	6.13	0.17	30	6.74	0.19	38
	F	8.28*	0.13	58	8.77	0.16	54
	G	10.08	0.15	38	11.25	0.17	39
	H	11.82	0.13	66	13.28	0.24	35
P_1	D	4.84	0.21	25	4.97*	0.12	39
	E	6.51	0.15	44	7.08	0.19	52
	F	8.84	0.10	51	9.45	0.16	42
	G	10.80	0.15	32	11.56	0.13	31
	H	12.01	0.12	59	13.11	0.22	37
P_2	B				4.29	0.28	4
	C	4.63	0.27	29	4.91	0.05	26
	D	5.53	0.17	29	5.74*	0.13	27
	E	7.63	0.19	53	7.70	0.17	57
	F	9.55	0.14	41	9.92	0.16	38
	G	11.35	0.15	49	11.86	0.12	40
	H	13.62	0.27	29	14.47	0.29	20
M_1	E	4.75*	0.22	9	4.02	0.30	32
	F	5.35	0.15	18	5.67	0.06	20
	G	6.62	0.19	49	6.98	0.19	55
	H	8.96	0.10	137	9.54	0.17	108
M_2	A				3.00	0.27	4
	B	3.95	0.04	6	3.96	0.29	11
	C	4.97	0.14	14	4.81	0.17	31
	D	5.79*	0.12	44	6.10*	0.13	49
	E	8.59	0.10	50	8.95	0.13	43
	F	10.20	0.16	40	10.81	0.17	24
	G	11.89	0.11	46	12.00	0.17	52
Total *n*				223			222

* $p < 0.05$.

(WHO 1995). Maturity indicators, in this case dental formation stages, are discrete stages within the continuous process of maturation, are universal, appear sequentially, in the same sequence and in all children (see Cameron 2004). They should also be discriminatory and reliable (good intra- and inter-observer reliability). Many tooth formation stages have large variance and do not discriminate between children of the same age. Maturity indicators should also show completeness, i.e. increasing in prevalence from 0 to 100% within a

Table IX. Mean age (standard error) of dental formation stages in 4480 girls and 4522 boys (combined groups).

		Girls		Boys		
Tooth	Stage	Mean	SE	Mean	SE	Sex difference
I_1	E	4.35	0.09	4.46	0.15	0.11
	F	5.67	0.13	6.02	0.13	0.35
	G	6.68	0.10	6.95	0.10	0.27
	H	7.90	0.11	8.34	0.11	0.44
I_2	E	4.85	0.13	5.24	0.12	0.39
	F	6.40	0.07	6.63	0.12	0.23
	G	7.32	0.10	7.78	0.11	0.46
	H	8.81	0.11	9.33	0.10	0.52
C	E	6.01	0.13	6.62	0.11	0.61
	F	7.65	0.11	8.66	0.05	1.01
	G	9.88	0.11	11.05	0.11	1.17
	H	11.72	0.10	13.23	0.12	1.51
P_1	C	3.48	0.19	3.76	0.13	0.28
	D	5.26	0.13	5.46	0.11	0.20
	E	6.72	0.05	7.21	0.12	0.49
	F	8.92	0.04	9.19	0.11	0.27
	G	10.74	0.10	11.43	0.11	0.96
	H	12.24	0.11	13.04	0.12	0.80
P_2	B	3.80	0.21	3.92	0.21	0.12
	C	4.80	0.16	4.90	0.10	0.10
	D	6.12	0.15	6.35	0.13	0.23
	E	7.60	0.13	7.97	0.12	0.37
	F	9.36	0.10	9.83	0.12	0.47
	G	11.65	0.12	12.26	0.12	0.61
	H	13.47	0.14	14.12	0.14	0.65
M_1	E	3.92	0.16	4.00	0.13	0.08
	F	5.25	0.12	5.61	0.09	0.36
	G	6.37	0.11	6.80	0.11	0.43
	H	9.30	0.10	9.97	0.10	0.67
M_2	A	3.44	0.23	3.47	0.20	0.03
	B	3.86	0.11	4.00	0.17	0.14
	C	4.84	0.11	4.94	0.12	0.10
	D	6.34	0.14	6.74	0.13	0.40
	E	8.53	0.10	8.81	0.12	0.28
	F	10.20	0.12	10.68	0.11	0.48
	G	11.65	0.10	12.23	0.13	0.58
	H	14.78	0.16	15.25	0.15	0.47

relatively short period of time. Many of these points relate to the number and choice of stages and although Demirjian's eight stages have been adapted to include additional root stages (Tompkins 1996; Solari and Abramovitch 2002), these issues remain unresolved in assessing of tooth formation.

These findings support other work showing similarities in timing of dental growth events between groups. Histological evidence shows that duration of crown formation times between groups (northern European, southern African) varies little (Reid and Dean 2006).

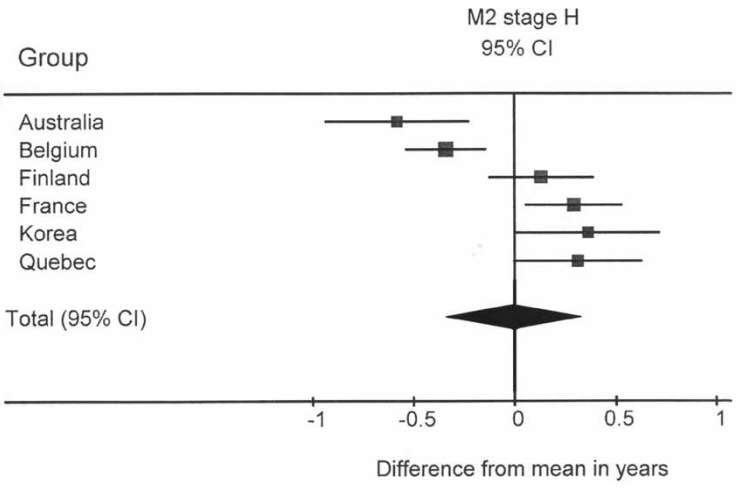

Figure 2. Forest plot of M_2 stage H (mature root apex) in girls plotted as difference from the total mean value in years.

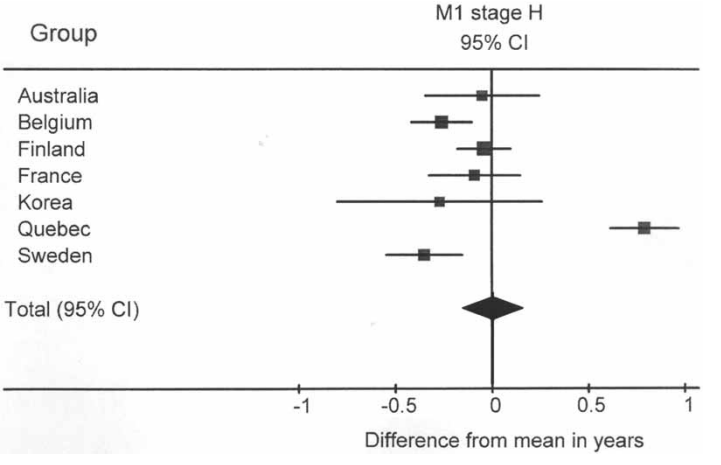

Figure 3. Forest plot of M_1 stage H (mature root apex) in girls plotted as difference from the total mean value in years.

Methods of assessing dental maturity using Bayesian statistics suggest that several populations (France, Ivory Coast, Iran) are similar although their sample includes only small numbers of young children and is uneven in age distribution (Braga et al. 2005).

Clearly there are gaps in our knowledge and understanding of the timing of dental maturation between human groups, for instance, little published data exist for children from Africa although several studies are underway. What seems clear is that the groups in this study do not differ greatly or consistently in the timing of Demirjian's tooth stages. Timing of tooth stages is used daily in the clinical setting, however as dental maturation is largely genetically controlled (Pelsmaekers et al. 1997) and less sensitive to environmental insult compared to other systems, the developing dentition is also used to predict age in forensic science, archaeology and anthropology. For this purpose results in Table X are presented of

Table X. Mean ages of children 'in a tooth formation stage' (combined groups).

		Girls				Boys				Girls and boys		
Tooth	Stage	Mean	SE	SD	*n*	Mean	SE	SD	*n*	Mean	SE	SD
I_1	D	4.06	0.08	1.01	163	4.21	0.08	1.19	225	4.15	0.06	1.12
	E	5.14	0.04	0.74	298	5.38	0.05	1.00	427	5.28	0.04	0.91
	F	6.36	0.05	0.87	270	6.61	0.05	0.82	309	6.49	0.04	0.85
	G	7.66	0.04	0.89	462	8.00	0.05	1.06	562	7.85	0.03	1.00
I_2	C	3.38	0.13	0.70	29	3.82	0.11	0.73	42	3.64	0.09	0.75
	D	4.42	0.06	0.96	254	4.68	0.06	1.08	389	4.58	0.04	1.04
	E	5.71	0.05	0.87	337	6.03	0.05	1.05	437	5.89	0.04	0.99
	F	7.06	0.04	0.80	353	7.49	0.05	0.95	432	7.30	0.03	0.91
	G	8.31	0.04	0.98	645	8.83	0.04	1.10	688	8.58	0.03	1.08
C	C	4.15	0.08	1.02	174	4.54	0.07	1.19	330	4.40	0.05	1.15
	D	5.35	0.05	1.03	372	5.82	0.05	1.14	514	5.63	0.04	1.12
	E	7.08	0.04	0.97	544	7.74	0.04	1.07	749	7.46	0.03	1.08
	F	8.81	0.03	1.08	996	9.78	0.04	1.22	1069	9.31	0.03	1.25
	G	10.85	0.04	1.28	821	12.02	0.05	1.33	819	11.43	0.04	1.43
P_1	B	3.57	0.18	1.31	56	3.78	0.08	0.69	69	3.68	0.09	1.02
	C	4.73	0.04	0.78	308	4.99	0.05	1.10	436	4.88	0.04	0.99
	D	6.26	0.05	0.96	408	6.64	0.04	1.04	559	6.48	0.03	1.03
	E	7.92	0.03	0.93	798	8.35	0.04	1.05	808	8.14	0.03	1.02
	F	9.77	0.04	1.14	893	10.29	0.04	1.24	930	10.04	0.03	1.22
	G	11.46	0.05	1.18	659	12.14	0.05	1.23	591	11.78	0.04	1.25
P_2	A	4.14	0.16	1.43	78	4.32	0.14	1.37	90	4.24	0.11	1.39
	B	4.79	0.07	0.88	160	4.86	0.07	1.07	223	4.83	0.05	1.00
	C	5.90	0.07	1.24	340	6.02	0.06	1.22	448	5.97	0.04	1.23
	D	7.29	0.05	1.09	496	7.46	0.05	1.16	577	7.38	0.03	1.13
	E	8.54	0.04	1.14	745	9.06	0.04	1.23	777	8.81	0.03	1.21
	F	10.51	0.04	1.29	975	10.98	0.05	1.43	958	10.74	0.03	1.38
	G	12.33	0.05	1.32	701	12.94	0.06	1.42	633	12.62	0.04	1.40
M_1	D	3.74	0.08	0.77	101	4.02	0.12	1.40	138	3.90	0.08	1.18
	E	4.87	0.06	0.97	249	5.06	0.05	1.04	362	4.98	0.04	1.02
	F	6.04	0.05	0.92	314	6.42	0.06	1.17	437	6.25	0.04	1.09
	G	8.22	0.04	1.28	1194	8.66	0.04	1.40	1302	8.45	0.03	1.36
M_2	A	4.05	0.11	0.67	41	4.07	0.07	0.55	66	4.06	0.06	0.60
	B	4.63	0.06	0.84	175	4.83	0.06	0.86	216	4.74	0.04	0.85
	C	6.01	0.05	1.04	402	6.13	0.05	1.15	564	6.08	0.04	1.10
	D	7.67	0.04	1.05	793	7.96	0.04	1.13	800	7.81	0.03	1.10
	E	9.35	0.04	1.11	735	9.71	0.04	1.14	797	9.54	0.03	1.14
	F	10.84	0.04	1.06	629	11.34	0.05	1.18	575	11.08	0.03	1.15
	G	12.92	0.04	1.41	1098	13.42	0.05	1.43	998	13.16	0.03	1.44

mean age of children 'in a stage' and the end stage (mature root apex) is omitted as it is not possible to predict how much time has passed since the child entered this stage.

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Appendix

Tooth notation:

- I_1 Permanent mandibular central incisor
- I_2 Mandibular lateral incisor
- C Mandibular canine
- P_1 Mandibular first premolar
- P_2 Mandibular second premolar
- M_1 Mandibular first molar
- M_2 Mandibular second molar

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Résumé. *Arrière plan:* On pense que les différences globales dans la méthode de Demirjian et al. d'appréciation de la maturité dentaire sont dues à des différences entre populations.
Objectif: Cette étude a pour objet d'observer la chronologie individuelle des stades de formation de la dent chez des enfants de huit nations.
Type de recherche: Il s'agit d'une méta-analyse de données d'enquêtes transversales rétrospectives de maturité dentaire déjà publiées
Méthode: Des données de radiographie panoramique de dents permanentes mandibulaires en voie de développement (stades de Demirjian) ont été recueillies en Autriche, Belgique, Canada, Angleterre, Finlande, France, Corée du Sud et Suède ($n = 9002$, âges de 2 à 16,99 ans). L'âge d'atteinte a été calculé au moyen de régressions logistiques pour chaque groupe par sexe et par méta-analyse de la totalité.
Résultats: Les ages moyens de chaque groupe et de l'ensemble sont significativement différents dans 65 comparaisons sur 509 ($p < 0{,}05$). Quelques différences sont de faible ampleur, mais sans qu'on puisse leur attribuer une signification particulière. La fermeture de l'apex de la première molaire est significativement plus Tardif chez les enfants du Québec, ce qui pourrait expliquer les differences observées dans les scores de maturité dentaire.
Conclusion: Ces résultats suggèrent qu'il n'existe pas de différence majeure entre ces enfants dans la chronologie des stades de formation dentaire. Il n'est donc pas possible d'expliquer les différences trouvées dans des études antérieures par la méthode de maturité dentaire de Demirjian.

Zusammenfassung. *Hintergrund:* Globale Unterschiede bei der Methode nach Demirjian et al. zur Bestimmung der Zahnreife werden ethnischen Unterschieden zugeschrieben.
Ziel: Das Ziel dieser Studie war, die zeitliche Abfolge der individuellen Zahnentwicklung bei Kindern aus acht Ländern zu untersuchen.
Untersuchungsaufbau: Dies war eine Meta-Analyse früher publizierter Daten aus retrospektiven Querschnittsuntersuchungen zur Zahnreife.
Methode: Es wurden Daten aus Australien, Belgien, Kanada, England, Finnland, Frankreich, Südkorea und Schweden von Panorama-Röntgenaufnahmen der unteren bleibenden Zähne (Demirjian-Stadien) ($n = 9002$, Alter 2–16,99 Jahre) zusammengefasst. Das Alter zum Zeitpunkt des Zahndurchbruchs wurde unter Verwendung einer logistischen Regression geschlechtsspezifisch für jede Gruppe

gerechnet und eine Meta-Analyse des gesamten Datensatzes vorgenommen. Überlappungen der 95%-Vertrauensintervalle von Mittelwerten wurden im Sinne nicht-signifikanter Unterschiede gedeutet.
Ergebnisse: Mittleres Alter für jede Gruppe und insgesamt waren bei 65 von 509 Vergleichen signifikant unterschiedlich ($p < 0{,}05$). Einige Stichproben waren klein, aber es gab hier kein durchgehendes Muster. Der Zahnschluss der ersten Molaren war bei Kindern aus Quebec signifikant später, und dies könnte die beobachteten Unterschiede im Zahnreifungs-Score erklären.
Zusammenfassung: Diese Ergebnisse legen nahe, dass es keine wesentlichen Unterschiede in der zeitlichen Abfolge der Zahnentwicklung dieser Kinder gibt. Damit wurden früher beobachtete Unterschiede bei Anwendung der Zahnreifebestimmungsmethode nach Demirjian nicht bestätigt.

Resumen. *Antecedentes:* Se cree que las diferencias globales en el método de Demirjian et al. para estimar la madurez dental son debidas a diferencias poblacionales.
Objetivo: El objetivo de este estudio fue investigar el momento de aparición de los estadios de formación dental individual en niños de ocho países.
Diseño de la investigación: La investigación consistió en un meta-análisis de datos previamente publicados procedentes de estudios transversales retrospectivos de madurez dental.
Método: Se combinaron datos de dientes permanentes en desarrollo de la mandíbula, a partir de radiografías panorámicas (estadios de Demirjian) procedentes de Australia, Bélgica, Canadá, Inglaterra, Finlandia, Francia, Corea del Sur y Suecia ($n = 9.002$, edades de 2,00–16,99 años). La edad de finalización se calculó utilizando una regresión logística para cada grupo y sexo y un meta-análisis del total. Un solapamiento del 95% de los intervalos de confianza de las medias se interpretó como que no existía ninguna diferencia significativa.
Resultados: Las edades medias para cada grupo y para el total fueron significativamente diferentes en 65 de las 509 comparaciones ($p < 0{,}05$). Algunas de éstas fueron de pequeño tamaño muestral, pero no existía un patrón consistente. El cierre apical del primer molar fue significativamente más tardío en los niños de Québec y esto podría explicar las diferencias encontradas en la puntuación de la madurez dental.
Conclusiones: Estos resultados sugieren la no existencia de diferencias importantes en el momento de aparición de las etapas de la formación del diente entre estos niños. Esto no permite explicar los resultados previos sobre las diferencias observadas cuando se usa el método de la madurez dental de Demirjian.