Original Research Article

Secular Trends in the Maturation of Permanent Teeth in 5 to 6 Years Old Children

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Objectives: This investigation aimed to evaluate the secular trend exhibited by developing permanent teeth in 5 to 6 years old southern Chinese children.

Methods: Four hundred radiographs of children born in the years 1981 ($n = 200$) and 2001 ($n = 200$) were randomly selected, and then age and gender matched. Maxillary and mandibular teeth on the left side were scored. The number of tooth developmental stages (n-tds) for each stage of development and total n-tds in crown and root development was calculated. Logistic regression, X^2 test for occurrence of trend and Fisher's exact test were used to evaluate the variations in n-tds between crown and root maturation and also maturation among different teeth. Dental maturation between boys and girls was also compared.

Results: In the maxillary dentition, children born in 2001 showed advanced dental maturation (odds ratio, 1.29; $P = 0.001$), and girls exhibited earlier maturation than boys (odds ratio, 1.43; $P = 0.001$). In the mandibular dentition, no significant difference between the years was observed (odds ratio, 0.97; $P = 0.761$), however, girls showed accelerated development than boys (odds ratio, 1.26; $P = 0.002$). Variations in maturation were also observed between individual tooth in the same arch and between the arches.

Conclusions: Children born in 2001 demonstrated accelerated dental development only in the maxillary dentition. Girls born in 1981 and 2001 exhibited advanced maturation than boys. Variations in development among different teeth in the year groups indicate the need for inclusion of all developing teeth to establish a secular change. Am. J. Hum. Biol. 25:329–334, 2013. © 2013 Wiley Periodicals, Inc.

INTRODUCTION

The developing dentition has been used as a predictor to evaluate the growth and maturity of an individual. This approach is used in clinical dentistry for appropriate treatment planning and in forensic dentistry for estimating the age of an individual with no documented birth records. Dental development follows a systematic growth pattern and this is influenced by genetic and environmental factors. Correlations between tooth formation, tooth eruption, skeletal maturity, sexual maturity, height, and weight have been demonstrated (Anderson et al., 1975). Since dental maturity is influenced by genetic factors, variations in dental maturation have been observed between different ethnic and population groups. Significant differences in dental maturation have been reported and Australian children were found to have accelerated maturation than children from other ethnic origins (Chaillet et al., 2005).

Changes in sexual, skeletal, and dental maturation have occurred over many years predominantly due to environmental changes and also nutritional influences. The average age of attainment of menarche has decreased by 2 to 3 months per decade since the middle of the last century (Wyshak and Frisch, 1982). Secular trends in stature and weight have been reported in southern Chinese children born in the 1960s and 1980s (Ling and King, 1987). The latter were found to be heavier and taller compared with those born in the 1960s. Similarly, advancement in sexual maturation has been reported in both southern Chinese boys and girls (Huen et al., 1997; Wong et al., 1996). In relation to the facial and oral structures, secular changes in face and stature dimension (Lavelle, 1972), transverse dental arch dimension (Lindsten et al., 2001), dental emergence (Rousset et al., 2003), and dental maturation (Cardoso et al., 2010) have been demonstrated. Tooth calcification follows a systematic pattern of growth that can be analyzed from a single panoramic radiograph and a large number of cases providing cross-sectional data. Various methods of staging dental development have been reported in the literature varying from 8 to 13 different stages (Demirjian et al., 1973; Haavikko, 1974; Nolla, 1960). The 8 stage method devised by Demirjian and co-workers is considered as the most reliable method for staging dental development (Dhanjal et al., 2006; Olze et al., 2005). It has also been established that dental development is identical on the right and left side of the arch (Demirjian et al., 1973; Pelsmaekers et al., 1997). Using dental staging method, secular trends has been reported between subjects born in different decades and centuries. It has been found that children who lived in 18th century had delayed dental development than children of 19th century (Liversidge, 1999). Based on the maturation of permanent mandibular canine teeth, advanced dental maturation was reported in children of 8

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to 14 years of age born in the 1990s compared to those born in the 1970s (Nadler, 1998).

The maturation and emergence of teeth are influenced by genetic and environmental factors (Garn et al., 1965). Girls tend to mature faster than boys in somatic development and this occurs until the pre-adolescent period. Similar trend has also been observed in dental maturation. A study conducted in Hong Kong found girls aged 6 to 13 years exhibited earlier dental maturation than boys (Lee et al., 1965). However, their analysis was restricted to children above six years of age. Although secular changes in human growth based on physical, sexual, and skeletal maturity have been extensively reported, there are only a few reports in the literature that have focused on dental maturity. The reported studies on dental maturity were performed on ethnic specific population groups, on subjects with wide age ranges and analysis was limited to only a few teeth.

Establishing secular trend standards for dental maturation allows modification in appropriate timing of treatment planning for specific age groups. In dental age assessments, this restricts the number of samples used to evaluate the applicability of a dataset, or to prepare population and time restrained reference dataset. Using dental maturation as an indicator, it was hypothesized that advanced dental maturation would be present in children born in 2001 and earlier development in girls. Children in the 5th year of life are of particular importance because dental maturity can be analyzed from all the developing permanent teeth, except the third molars. In addition, in this age group, variations in dental maturation can be analyzed from both crown and the root development of all permanent teeth. To date, no such study has been conducted on southern Chinese subjects or focusing on a specific age group. Thus, the aim of this study was to compare the variations observed in the dental maturation in five to six years old southern Chinese children born in 1981 and 2001.

MATERIALS AND METHODS

Samples

Four hundred dental panoramic tomographs (DPT) of 5 to 6 years old children were obtained from the archives of the Prince Philip Dental Hospital, Hong Kong. The subjects involved in the study were healthy children of southern Chinese ethnicity and the socio-economic status of the children in both groups was middle to upper middle class. These children were grouped into four categories based on their year of birth (1981 and 2001) and gender (boys and girls). For the 1981 group, two hundred (100 boys and 100 girls) DPT were randomly selected from the total of 800 DPT, which had been taken for a survey conducted in 1987. For the 2001 group, a sample of two hundred DPT (100 boys and 100 girls) were selected and age and gender matched with the 1981 group so that the age matches were similar between the samples, see Table 1. The age of the subjects in both year groups for boys and girls ranged from 5.01 years to 6.00 years (mean age 5.55 years, SD 0.27 years). These radiographs had been originally taken for diagnostic purposes and hence they were re-used for the present study. Ethics approval for this study was obtained from the Hospital Authority of Hong Kong West Cluster (IRB UB 11-182).

TABLE 1. Age and gender distribution of children born in 1981 and 2001

	1981		2001	
Age (in years)	Boys	Girls	Boys	Girls
5.01–5.10	10	10	10	10
5.11–5.20	10	10	10	10
5.21–5.30	10	10	10	10
5.31–5.40	10	10	10	10
5.41–5.50	10	10	10	10
5.51–5.60	10	10	10	10
5.61–5.70	10	10	10	10
5.71–5.80	10	10	10	10
5.81–5.90	10	10	10	10
5.91–6.00	10	10	10	10
Total	100	100	100	100
Mean age	5.55	5.54	5.55	5.55
Std. deviation	0.27	0.27	0.28	0.27

Scoring criteria

All of the DPT were scanned at a resolution of 360 dpi in a gray scale format (Canon, Canon Inc, Japan) and viewed on a wide screen monitor at a standard magnification of 160% (Microsoft Picture Manager, Microsoft Corp, US). Maxillary and mandibular teeth on the left side were scored on a score card using Demirjian's classification of tooth development stages (A-H). This classification system grades the radiographic appearance of developing teeth, designated in alphabets starting from "Stage A" signifying initial calcification to "Stage H" signifying closure of the root apex. A single trained and calibrated examiner (JJ) with an intra-examiner reliability score of kappa 0.85 analyzed all of the radiographs (Landis and Koch, 1977). For each subject, all of the developing permanent teeth on the left side were scored and each tooth was assigned a stage, for example, the upper left permanent central incisor at stage E was recorded as UL1E. When a tooth was missing on the left side, the corresponding tooth on the right side was scored.

Data analysis

The chronological age of the subjects was calculated by subtracting the date of birth from the date on which the radiograph was obtained. The details of each subject and the designated score for the stage of development of individual tooth was entered in the Microsoft Access database (Microsoft Corp, US) designed for the purpose of Dental Age Assessment study (Jayaraman et al., 2012). This calculates the mean Age of Attainment (AoA) for each tooth developmental stage for all of the fourteen developing permanent teeth. The details were then transferred to Microsoft Excel (Microsoft Corp, US) and the final pool consisted of 5600 data points (100 DPT x 2 years x 2 genders x 2 arches x 7 stages). The number of teeth at each tooth developmental stage (n-tds) was calculated independently for each maxillary and mandibular tooth morphology type (TMT). Furthermore, the development of the dentition was categorized into crown (Stages A to D) and root (Stages E to G) development and the n-tds was tallied. Statistical significance was set at $p < 0.05$ and SPSS software (Version 19.0, SPSS Inc, Illinois, Chicago, USA) was used for analysis. To analyze the variations among different teeth in the year 1981 and 2001 and between the

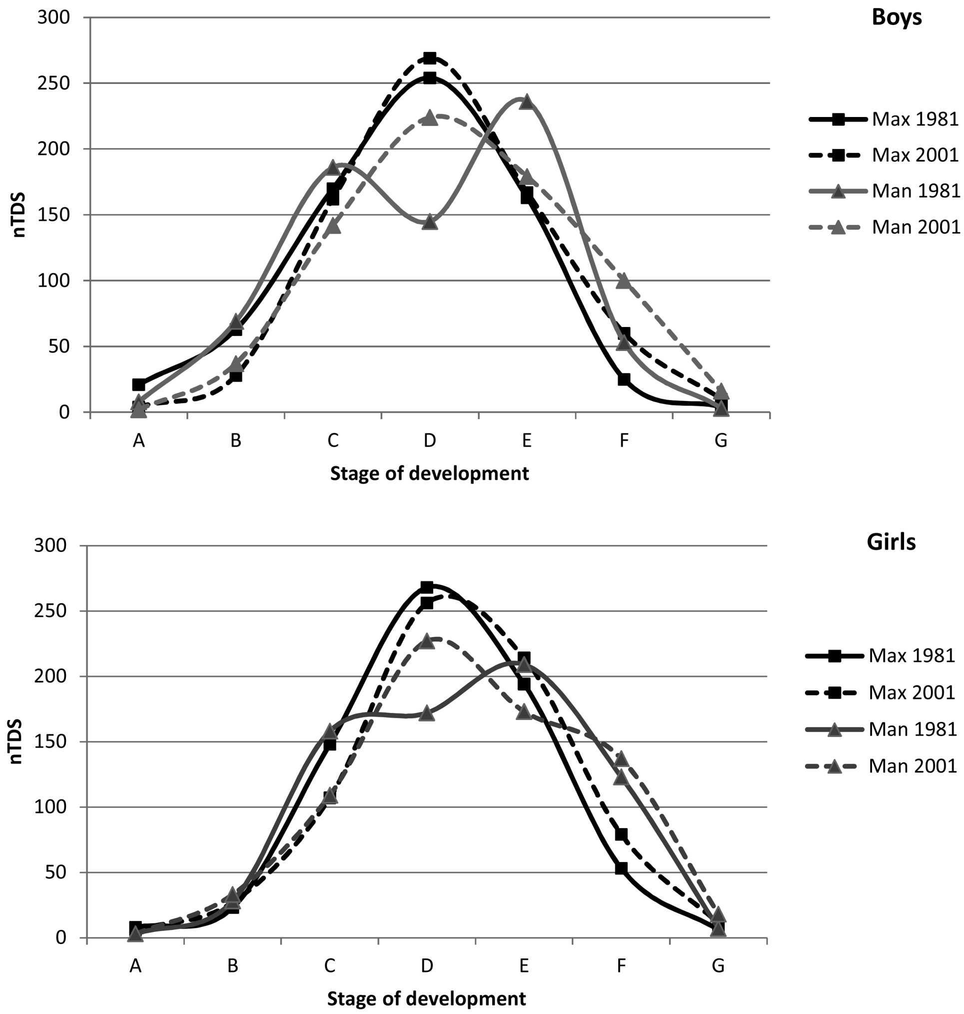

Fig. 1. Dental maturation based on crown and root development among boys and girls born in 1981 and 2001.

genders, Chi-square test for occurrence of trend or Fisher's exact test (when less than 20% of cells had an expected frequency less than five) was performed. Finally, to analyze the overall direction of the trend, multiple logistic regression analysis was performed in the n-tds in crown and root maturation between the year and the gender groups independently for the maxillary and mandibular dentition.

RESULTS

The chronological ages are not statistically different for boys born in 1981 and 2001 ($P = 0.977$) and girls born in 1981 and 2001 ($P = 0.995$). When the number of teeth at each stage of development was calculated, at a given point, high numbers of teeth were observed in Stage "D" in all the gender and year groups. This trend was not observed in the mandibular dentition in children born in 1981 who had high number at Stage "E" (see Fig. 1). None of the teeth achieved root completion (Stage H).

Significant variations between individual tooth maturation were observed among boys and girls born in 1981 and 2001. In boys, all the teeth exhibited variations ($P < 0.05$), except maxillary canine, mandibular canine and second molar ($P > 0.05$). In girls, most of the teeth did not exhibit a difference except for maxillary central incisor, lateral incisor, first premolar and mandibular second premolar ($P < 0.05$) (Tables 2 and 3).

When analyzing the n-tds in crown and root maturation among boys and girls born in 1981 and 2001, a significant difference was observed between each year and gender group. Multiple logistic regression analysis for the probability of having tooth at root maturation was performed independently for the maxillary and mandibular dentition (see Table 4). Higher n-tds in root maturation stages and a positive trend were observed in maxillary dentition in both boys and girls born in 2001; however, these variations were not observed in mandibular dentition.

In the maxillary dentition, the odds of having a tooth in the root development stages for children born in 2001 are 29% higher than the odds for children born in 1981, adjusted for the gender effect (odds ratio, 1.29; $P = 0.001$). Similarly, the odds of having a tooth in the root development stages for girls are 43% higher than the

TABLE 2. Stage of development and number of tooth developmental stages (n-tds) in the maxillary dentition of boys and girls born in 1981 and 2001

Dentition	Stage	Boys 1981	Boys 2001	Level of significance	Girls 1981	Girls 2001	Level of significance
Maxillary dentition							
Central Incisor	D	32	25		34	14	
	E	66	60		62	70	
	F	2	15	$P < 0.05^{\#}$	4	16	$P < 0.01^{\#}$
Lateral Incisor	D	81	56		50	29	
	E	19	37		48	63	
	F	0	7	$P < 0.01$	2	8	$P < 0.01^{\#}$
Canine	C	6	4		3	1	
	D	81	87		64	61	
	E	13	9	$P > 0.05^{\#}$	33	38	$P > 0.05$
1st Premolar	B	13	2		5	2	
	C	64	40		29	15	
	D	23	56		64	80	
	E	0	2	$P < 0.01$	2	3	$P < 0.05$
2nd Premolar	A	8	2		2	2	
	B	20	9		7	11	
	C	56	49		59	40	
	D	14	31		27	39	
	E	1	7		4	5	
	F	1	2	$P < 0.01$	1	3	$P < 0.05$
1st Molar	C	1	1		0	0	
	D	9	1		3	2	
	E	64	52		45	35	
	F	22	36		46	52	
	G	4	10	$P < 0.01$	6	11	$P < 0.05$
2nd Molar	A	13	2		6	2	
	B	30	17		11	16	
	C	43	68		57	51	
	D	14	13	$P < 0.01^{\#}$	26	31	$P < 0.05$

Fisher's Exact test, # Chi-square test for occurrence of trend.

TABLE 3. Stage of development and number of tooth developmental stages (n-tds) in the mandibular dentition of boys and girls born in 1981 and 2001

Dentition	Stage	Boys 1981	Boys 2001	Level of significance	Girls 1981	Girls 2001	Level of significance
Mandibular dentition							
Central Incisor	D	1	2		2	1	
	E	72	47		42	36	
	F	26	48		55	57	
	G	1	3	$P < 0.01$	1	6	$P > 0.05$
Lateral Incisor	D	9	15		5	8	
	E	86	68		76	67	
	F	4	16		18	22	
	G	1	1	$P < 0.01$	1	3	$P > 0.05$
Canine	C	7	1		2	1	
	D	84	87		54	65	
	E	9	12	$P > 0.05$	44	34	$P > 0.05$
1st Premolar	B	4	1		1	0	
	C	69	28		22	13	
	D	26	69		73	83	
	E	1	2	$P < 0.01$	4	4	$P > 0.05$
2nd Premolar	A	4	1		2	2	
	B	27	10		11	14	
	C	57	52		67	37	
	D	11	35		18	46	
	E	1	2	$P < 0.01$	2	1	$P < 0.01$
1st Molar	C	4	2		2	1	
	D	5	2		2	1	
	E	67	48		41	31	
	F	23	36		50	58	
	G	1	12	$P < 0.01$	5	9	$P > 0.05$
2nd Molar	A	4	1		1	1	
	B	38	26		16	19	
	C	49	59		65	57	
	D	9	14	$P > 0.05$	18	23	$P > 0.05$

Fisher's Exact test, # Chi-square test for occurrence of trend.

TABLE 4. Logistic regression models for the probability of having tooth at root maturation with number of tooth (n-tds) at crown and root maturation in boys and girls born in 1981 and 2001

	Crown	n %	Root	n %	OR (95% CI)	P value
Maxillary dentition						
Gender						
Girls	843	60.2	557	39.8	1.43 (1.22–1.67)	0.001
Boys (reference)	971	69.4	429	30.6	1	
Year						
2001	859	61.4	541	38.6	1.29 (1.10–1.51)	0.001
1981 (reference)	955	68.2	445	31.8	1	
Mandibular dentition						
Gender						
Girls	733	52.4	667	47.6	1.26 (1.09–1.46)	0.002
Boys (reference)	813	58.1	587	41.9	1	
Year						
2001	777	55.5	623	44.5	0.97 (0.84–1.13)	0.761
1981 (reference)	769	55.0	631	45.0	1	

OR, odds ratio; CI, confidence interval.

odds for boys born in years 1981 and 2001 (odds ratio, 1.43; $P = 0.001$). In the mandibular dentition, no difference was observed among children in the year groups (odds ratio, 0.97; $P = 0.761$); however, girls showed advanced maturation than boys (odds ratio, 1.26; $P = 0.002$).

DISCUSSION

Dental development encompasses two different processes: dental maturation and dental eruption. The former refers to the formation of tooth structure and the later refers to the movement of tooth and gingival emergence into the oral cavity. Premature extraction of primary molars has resulted in delayed eruption of premolars; however, the stage of dental development remained unaltered (Fanning, 1962). Since the stage of development was used in our analysis, it can be presumed that any resultant effect of early loss of primary molars had least influence to the outcome of the study. Moreover, it has been established that dental maturation is an ideal tool to evaluate variations since they are least disturbed by external factors (Adler, 1963). Panoramic radiograph serves as an excellent tool to analyze the developing dentition. Although this imaging technique results in 3–7% of magnification, the outcome remains unaffected since the evaluation is conducted on the absolute length measurement of the tooth and not the size (Demirjian et al., 1973).

In earlier studies, secular trend has been established either by analyzing a specific stage or multiple stages of development of a single tooth, or multiple teeth. The mandibular canine at developmental Stage "G" has been established as the best tool to estimate pubertal growth spurt (Coutinho et al., 1993). Similarly, the mandibular permanent canine was used to demonstrate secular trend in Caucasian subjects in the United States of America (Nadler, 1998). Our study is the first which analyzed secular trend from dental maturation of maxillary and mandibular teeth in a large random sample of children within in a specific age group. In this investigation, variations in the development among different permanent teeth were demonstrated but not all of them exhibited similar secular changes. It is understood that the rate of maturation and emergence is dependent on genetic control and that each tooth has its own ethnic-specific normal distribution for maturation. The reliability of using a specific tooth, for example, the canine, for analyzing secular changes is questionable. In addition, this study found no significant difference in maxillary and mandibular canines, although other teeth exhibited a difference (Tables 2 and 3). It is possible to conclude that a secular trend study would be complete only if all of the developing permanent teeth are included in the analysis.

Dental maturation is a sequential process that undergoes different stages before attaining complete development. Hence, to estimate the maturation differences, the number of tooth development stages (n-tds) in crown and root was calculated. A higher number of n-tds in root development and less in n-tds for crown development indicates advanced dental maturation. This comparison method was employed in this study to demonstrate secular changes in boys and girls born in 1981 and 2001. From Figure 1, it is observed that n-tds in maxillary and mandibular dentition in the year and gender groups shows variation in growth pattern. However, a relatively larger variation was observed only in stage "D" in which the n-tds in mandibular dentition of children born in 1981 was around 10% lesser than their counterparts. These findings imply that variations were also observed at n-tds among different developing teeth. The trend observed in this study reflects the maturation pattern of children belonging to southern Chinese ethnicity which might be different in the similarly aged children of a different ethnic group.

Maxillary and mandibular teeth exhibit variations in development. Mandibular teeth have been shown to exhibit advancement in both eruption and root maturation compared to the corresponding maxillary teeth (So et al., 1990). Although, initiation of tooth formation starts at the same time for each corresponding maxillary and mandibular teeth, the course of development varies among the two, with mandibular teeth showing advancement at the later stages (Hillson, 1996). It is certain that there exists a considerable variation in the dental development among these entities which is related to genetic and neurological development. In this study, secular trend was observed only in the maxillary dentition, but not in the mandibular dentition. From this result, it is prudent that the year effects did not affect the mandibular dentition as the children born in 1980 and 2000 exhibited similar development pattern. Evidence of the secular trend may become more marked at a later stage when the children enter their active growth spurt. Moreover, this study was conducted to test secular changes in children within a specific age group; the obtained differences amongst the two groups were minimal. It can be argued that a minimal secular trend has occurred in the two decades.

Secular trends have been reported in normal healthy individuals (Cardoso et al., 2010; Nadler, 1998). Similarly, delayed dental development has been demonstrated in children with cleft lip and palate; morphological and genetic determinants have been implicated (Lai et al., 2009). Secular changes have been usually demonstrated by evaluating the average age of attainment of developing dentition (Coutinho et al., 1993; Nadler, 1998). In our study, n-tds based on crown and root development was utilized because the ages of the subjects included were limited to a defined age range (5.01 and 6.00 years). Since the subjects born in 1981 and 2001 were age-matched, the average age of attainment in mean decimal years could not be analyzed. Consequently, the age was kept as a constant and n-tds at different stages of crown and root development was analyzed. For this reasons we did not demonstrate the degree of variation in chronological years.

Girls mature faster than boys and this was reflected this study in which advanced dental maturation was observed in the girls born in 1981 and 2001. It has been shown that girls show a more advanced rate of dental development at 8 years and this reached a peak at 13 years; they were on average one year in advance of the boys at the equal chronological age (Holtgrave et al., 1997). The rates of tooth formation and emergence changes at the time of puberty are due to hormonal changes. Apart from the strong genetic influence, nutrition and socio-economic status also influence the rate of dental maturation and eruption (Garn et al., 1965; Pelsmaekers et al., 1997). Hence, every reasonable effort was taken to match the two population samples in this study (see Table 1). The subjects born in 1981 and 2001 were age-matched and they were of similar socio-economic status. This is considered important as one study found significant differences in the rate of dental development among children belonging to low, middle and high socio-economic status (Lee et al., 1965). A possible limitation of this study was that the radiographs could not be blinded for analysis since the size of the films taken in 1981 and 2001 were different. The films were taken using different x-ray units and even after scanning, it was difficult to mask the difference.

CONCLUSIONS

This study strongly suggests accelerated dental development in children born in 2001. In the maxillary dentition, subjects born in the year 2001 showed accelerated dental maturation compared with their counterparts born in 1981, adjusted for their gender. When comparing boys and girls born in 1981 and 2001, girls exhibited advancement in maturation than boys. Variations among individual tooth maturation in the year and gender groups and between the maxillary and mandibular arches indicate the need for inclusion of all developing teeth for establishing secular trends.

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