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ORIGINAL RESEARCH

Secular changes in dental development of Korean children aged 4 to 16 years over a 10-year period

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Abstract

This study evaluated 10-year secular changes in dental maturity and dental development among Korean children. A retrospective analysis of panoramic radiograph samples from Korean children (4–16 years old) taken in 2010 and 2020 was conducted. The 2010 group consisted of 3491 radiographs (1970 boys and 1521 girls), and the 2020 group included 5133 radiographs (2825 boys and 2308 girls). Using Demirjian's method, dental maturity scores and dental developmental stages were assessed. For intra-observer reliability, Weighted Cohen's kappa was used, and Mann-Whitney U tests were performed to compare the 2020 and 2010 groups. A slight acceleration in dental maturity was observed in both boys and girls, with the difference being more noticeable in boys at an earlier age. Statistically significant differences were noted at ages 4, 5 and 7 for boys, and at age 6 for girls. Despite these differences, the individual dental development stages of 2020 and 2010 showed inconsistent trends with limited differences. Generally, girls demonstrate more advanced dental maturity than boys. A slight acceleration in Korean children's dental maturity was observed over a 10-year period when comparing the 2020 groups to the 2010 groups.

Keywords

Dental maturity; Dental development; Forensic odontology; Secular change

1. Introduction

Dental maturity is a reliable biological indicator of chronological age since tooth development is less affected by external factors [1, 2]. Skeletal, sexual, somatic and dental maturity are common biological maturation indicators, with dental maturity exhibiting a low correlation with other indicators and progressing independently [3, 4]. Dental maturity can be measured to understand the influence of genetics and the environment on dental development timing and rate. Further, it allows comparison of maturity between different groups or with the 50th percentile of a reference group [5]. Dental maturity can be assessed from counting erupted teeth to evaluating dental calcification on radiographs [4, 5]. Demirjian's method, which evaluates the development of seven permanent teeth in the left mandible through panoramic radiographs, is the most widely used method [6, 7]. Based on the degree of calcification in the root and crown, Demirjian's method categorizes each tooth into eight stages, ranging from A (indicating "no fusion of calcified points") to H (indicating "the apical end of the root canal is completely closed") [8]. This simple and reliable maturity scoring system quantifies dental maturity and correlates with chronological age [5, 6].

As dental maturity is affected by genetics and the environment [9, 10], ethnic variations have been observed, as well as secular changes [5, 11]. The differences in dental maturity patterns among diverse populations suggest the need for population-specific studies to better understand developmental patterns in each group [11–13]. Additionally, secular trends in dental development across different populations show mixed results. According to Kaygisiz *et al.* [14] (2016) Turkish children did not show significant secular trends in dental maturity between the 1980s and the 2000s, while Sasso *et al.* [15] (2013) discovered a significant acceleration in dental development of 0.72 years over a 30-year period in Croatian children. Over the last 30 years, only boys have accelerated dental development in the European population, according to Holtgrave *et al.* [16] (1997). Jayaraman *et al.* [17] (2013) reported accelerated dental development only in the maxillary dentition among 5- to 6-year-olds.

Studies on epidemiological growth are crucial for assessing the environmental influences and evaluating the health status of individuals and populations; as Tanner phrased, "Growth is a mirror of the conditions of society" [18, 19]. Secular change is a marker of populations' public health, reflects changes over time and provides insights into how growth and the environment are connected [20]. To ensure accurate diagnosis and treatment planning in clinical practice and to estimate age in forensic odontology, it is imperative to evaluate dental development in a specific population at certain intervals. Both Korean boys and girls had changes in height and body mass index over a 10-year period [21, 22], but there aren't enough studies on secular changes in dental development. Therefore, this study aimed to determine whether Korean children aged 4–16 years showed a difference in 10-year secular changes in dental development using Demirjian's method.

2. Materials and methods

2.1 Sample collection

A retrospective study was conducted on two groups of panoramic radiograph samples from Korean children, categorized by year of panoramic radiographs. The 2010 group consisted of 3491 radiographs (1970 boys and 1521 girls) recorded during 2010–2011. The 2020 group included 5133 radiographs (2825 boys and 2308 girls) recorded during 2020–2021. The panoramic samples were retrieved from the archives of the Department of Pediatric Dentistry, Seoul National University Dental Hospital. Study participants were healthy children aged 4 to 16 years of Korean ethnicity.

This study excluded: (1) Systemic diseases or genetic disorders that affect skeletal and dental growth, poor-quality panoramic radiographs. (2) History of orthodontic treatment. (3) History of permanent teeth extraction. (4) Congenitally missing teeth on the left side of the mandible. (5) Localized oral pathology, anomalies, or impacted teeth that may affect dental development.

Table 1 represents the study groups by their age and sex distributions. To calculate a subject's chronological age, the date of birth was subtracted from the date of the panoramic radiograph and then converted to decimal age.

TABLE 1. Age and sex distribution of the study groups.

	Group 2010		Group 2020	
	Boys	Girls	Boys	Girls
Age				
4.0–4.99	169	114	175	144
5.0–5.99	207	139	286	201
6.0–6.99	236	173	366	272
7.0–7.99	255	184	365	316
8.0–8.99	230	209	343	287
9.0–9.99	249	188	359	293
10.0–10.99	204	170	311	276
11.0–11.99	172	132	217	191
12.0–12.99	127	102	174	133
13.0–13.99	59	52	111	106
14.0–14.99	40	40	74	53
15.0–15.99	22	18	44	36
Total	1970	1521	2825	2308
Mean age	8.67	8.85	8.84	8.93
Standard deviation	2.70	2.70	2.69	2.69

2.2 Dental development assessment using Demirjian's method

The dental development of both groups was analyzed according to Demirjian's method [8]. The seven teeth in the left mandible were classified into eight stages, ranging from A "no fusion of calcified points" to H "the apical end of the root canal is completely closed". Based on the stage of each tooth, a biologically weighted score was assigned to boys and girls. Scores are summed to determine dental maturity, measured on a scale from 0 to 100. The assessments were all performed by a single skilled pediatric dentist.

2.3 Statistical analysis

An assessment of intra-observer reliability was performed with Weighted Cohen's Kappa analysis using MedCalc® Statistical Software (version 20.100; MedCalc Software Ltd, Ostend, Belgium). We re-examined 200 randomly selected radiographs 2 weeks after the first evaluation to assess each tooth's developmental stage. Weighted Cohen's Kappa was calculated to be 0.944, indicating an "almost perfect" agreement. In SPSS 25 (IBM Corp., Armonk, NY, USA), the Mann-Whitney U test was used to analyze the differences in dental maturity scores for each age group in the 2020 and 2010 groups. Data are presented as a median and interquartile range, and $p < 0.05$ was considered statistically significant.

3. Results

Dental maturity scores were determined for each age group in both the 2020 and 2010 groups (Table 2), and 10-year secular changes were evaluated (Fig. 1). The 2020 group showed significantly higher maturity scores for 4, 5 and 7-year-old boys, and 6-year-old girls ($p < 0.05$). However, the differences between boys and girls did not appear significant. Girls in both the 2020 and 2010 groups generally displayed more advanced dental maturation than boys (Table 2). Notably, among the groups with the largest difference in scores were the 8-year-old group in 2020 and the 7-year-old group in 2010.

For the 2020 and 2010 groups, dental development assessments focused on the Demirjian E, F and G stages of the seven left mandibular teeth were conducted (Fig. 2). For each tooth, there was a difference in median age of less than 6 months between both groups. Therefore, it is impossible to detect significant secular changes in dental development. Time taken for the dental development process was assessed by calculating the median age difference between stages G and E. The longest period was recorded for canines, averaging 4.5 years (2020 Boys: 4.7, 2010 Boys: 4.7, 2020 Girls: 4.2, 2010 Girls: 4.4). In contrast, the shortest period was recorded for central incisors, averaging 2.4 years (2020 Boys: 2.3, 2010 Boys: 2.4, 2020 Girls: 2.2, 2010 Girls: 2.4).

In Fig. 2, girls in both the 2020 and 2010 groups demonstrated consistently more advanced dental development than boys in all E, F and G stages of all seven teeth. Girls and boys in the 2020 group differed by an average of 0.2, 0.2, 0.7, 0.3, 0.3, 0.3, 0.3 years in stages E, F and G from central incisor to second molar, which were 0.2, 0.2, 0.7, 0.3, 0.3, 0.3 and 0.3 years, respectively. Accordingly, the 2010 group had

TABLE 2. Dental maturity score differences between 2020 and 2010 groups for each age group.

	Boys			Girls			Differences in boys and girls	
	2020	2010	*p* value	2020	2010	*p* value	2020	2010
Age								
4.0–4.99	24.47	24.33	0.023*	23.15	23.49	0.228	0.14	−0.34
5.0–5.99	39.65	42.82	0.026*	37.67	40.78	0.092	−3.17	−3.11
6.0–6.99	55.46	60.15	0.573	55.18	58.44	0.035*	−4.69	−3.26
7.0–7.99	70.54	74.58	<0.001*	68.04	74.76	0.814	−4.04	−6.72
8.0–8.99	80.93	86.15	0.195	81.53	86.07	0.435	−5.22	−4.54
9.0–9.99	88.99	92.29	0.877	88.46	92.28	0.601	−3.30	−3.82
10.0–10.99	92.38	94.81	0.556	92.47	94.69	0.490	−2.43	−2.22
11.0–11.99	93.84	96.32	0.288	93.93	96.16	0.207	−2.48	−2.23
12.0–12.99	95.38	97.45	0.143	95.24	97.49	0.634	−2.07	−2.25
13.0–13.99	96.91	98.64	0.159	97.32	98.39	0.344	−1.73	−1.07
14.0–14.99	98.79	99.30	0.242	99.06	99.18	0.516	−0.51	−0.12
15.0–15.99	99.49	99.46	0.978	99.35	99.83	0.081	0.03	−0.48

p value from Mann-Whitney U test. $*p < 0.05$.

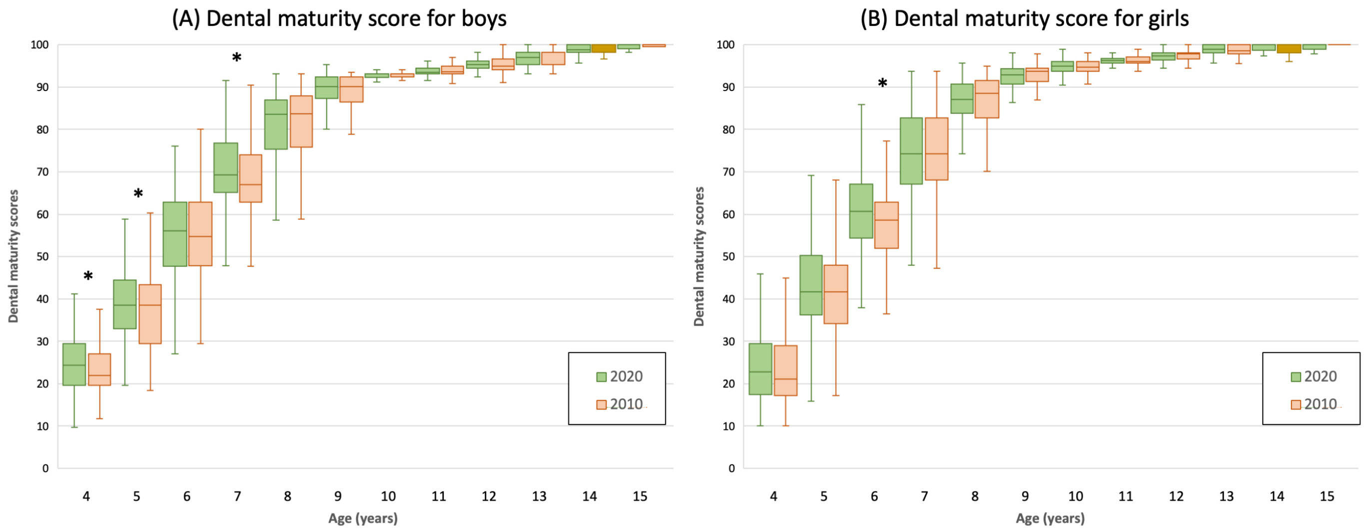

FIGURE 1. Comparison of median dental maturity scores. (A) Dental maturity score for 2020 and 2010 boys. (B) Dental maturity score for 2020 and 2010 girls. Box plots show medians and interquartile ranges of the data. $*p < 0.05$ in Mann-Whitney U test.

differences of 0.2, 0.3, 0.7, 0.4, 0.2, 0.2 and 0.3 years. Girls' stages E, F and G in all seven teeth on average were 0.3 years older than boys in both the 2020 and 2010 groups. Both groups showed the largest differences in canines (0.7 years), and the smallest differences in central incisors (0.2 years).

4. Discussion

"Secular change", or "secular trend", refers to the changing pattern of somatic development in children within a specific population from generation to generation [23]. There may be positive changes (when body sizes increase) or negative changes (when they decrease) [24]. Almost all industrialized countries consistently display a trend towards increasing heights and accelerating maturity [25], but the underlying mechanisms remain unclear. Genetic and environmental factors contribute to secular change, with an emphasis on environmental factors. Observing a secular trend in DNA sequences in DNA sequences may be difficult due to the time taken to observe genetic changes in a population, which are inherently long-term processes [26]. In contrast, socio-economic changes, along with the nutritional, hygienic and health status of society, appear to be the most probable causes of secular change [23–25], as growth reflects society's conditions [19].

Secular change studies should therefore always consider time and place, and a separate study should be conducted for each population, since different outcomes may result from different ethnicities and societies [24]. Due to the lack of a standardized time period for studies of dental development secular change, as well as the uncertainty of influencing so-

FIGURE 2. Comparison of median age at dental development stages. (A) Median age at dental development stages for 2020 and 2010 boys. (B) Median age at dental development stages for 2020 and 2010 girls. Box plots show medians and interquartile ranges of the data.

cioeconomic factors, direct comparisons between the results are challenging. There have been varying findings in previous studies on secular changes in dental development in Turkish, Croatian, Chinese, Portuguese and European children, with the majority finding advanced (positive) or no secular changes [14–17, 27]. Korean boys and girls showed slight improvements in dental maturity scores over a 10-year period in this study. According to a European children's study, boys under 10 showed a small acceleration of dental development compared to girls [16]. Therefore, determining the maturation speed of dental development with the standard percentile in young children may be inaccurate if not regularly updated. Changes in environmental factors over time seem to affect outcomes differently by gender. Further, since advancements only occurred at a young age and did not persist through dental development, it is possible that secular changes in dental development could result in diverse outcomes for each tooth. This is likely due to the fact that each tooth matures at different ages and mineralization speeds vary [28].

The Demirjian stages E, F and G for each tooth were chosen for evaluation to simplify the comparison among the seven teeth Panoramic radiographs are not routinely taken at a young age, so early stages of tooth development are limited for some teeth. Most differences between the two groups were within a month or two, with certain stages either being advanced or delayed in 2020. This implies that a 10-year period may not be sufficient to detect significant changes in dental development. Nevertheless, individual tooth analysis identified different root formation times (mean age difference between stages G and E), with canines taking the longest time. The canine showed the largest gap (0.7 years) in mean ages between boys and girls in each developmental stage attainment. The same findings have been reported regarding the canine in previous studies on French-Canadian [29] and Japanese children [30]. Therefore, it is necessary to consider the changes of each tooth individually and the total dental maturation score, when conducting secular studies of the dental development process.

Dental development is considered a measure of physical maturity along with skeletal and pubertal maturity [31]. However, the same environmental factors may have different impacts on these processes, with genetic factors being more influential on dental development than environmental factors [10].

Similarly, Korean children showed only a slight acceleration in dental maturity over a 10-year period, whereas secular changes in height, weight and menarcheal age were reported in previous studies [22, 32]. Environmental factors influence teeth development less than other maturation indicators [33], but it begins during the intrauterine period and lasts for up to 17 years. This complex process can also be influenced by a multitude of genetic and environmental factors over a long period of time, resulting in considerably different tooth mineralization timing among populations [15]. A number of explanations have been postulated for the trend toward earlier maturity, but the underlying causes remain unclear. Secular changes are primarily influenced by improved living conditions, sanitation and overall public health, reflected in the marked reduction in infant and childhood mortality and morbidity [4]. Different populations and eras may have different times of initiation, rates of formation, and morphologies of teeth, so considering secular changes may enhance prediction precision when assessing dental maturity and age, both in clinical settings and in forensic odontology [34].

The study limits socio-economic information, and environmental background changes of the samples are not available for analysis. Periodic reassessment of dental development requires further research, as do secular studies with longer intervals. For a comprehensive understanding of the etiology of dental developmental, it is necessary to identify correlated exogenous factors that affect secular changes in dental development, develop population-specific dental maturity tables, and analyze each tooth individually.

5. Conclusions

A slight acceleration in Korean children's dental maturity was observed over a 10-year period when comparing the 2020 groups with the 2010 groups. This study suggests that secular changes in dental development tend to be more prominent in boys at a younger age and may differ between individual teeth.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

AUTHOR CONTRIBUTIONS

SHO and YJK—designed the research study and wrote the manuscript. HTK, JSS and TJS—collected and analyzed the data. ISC, HKH and KTJ—reviewed and edited the manuscript. All authors read and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This retrospective study was conducted according to the guidelines of the Declaration of Helsinki and all procedures performed were in accordance with the Ethics Committee of the Seoul National University Dental Hospital, Seoul, Korea (Ethics Code: ERI23026). The requirement for informed consent was waived by the Ethics Committee of the Seoul National University Dental Hospital for this retrospective study since the data and patient details were anonymized.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Hong-Keun Hyun is serving as one of the Editorial Board members of this journal. We declare that Hong-Keun Hyun had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to LAAA.

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