Correlation between Dental Maturity and Body Mass Index in Korean Children

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Objective: *The aim of this study was to determine relationships between dental maturity and body mass index (BMI) in Korean children.* ***Study Design***: *600 Korean children aged between 5 and 10 years for whom panoramic radiographs have been obtained between 2010 and 2017 were selected. Subjects were divided into four weight-status groups: underweight, normal weight, overweight, and obese. Five lower-left permanent teeth were observed and rated. The stage of each tooth was converted into a score using the table suggested by Demirjian, and the sum of these scores was designated as the 'maturity score'.* ***Results***: *This study found statistically significant differences in dental maturity between the weight groups (analysis of variance, P=0.003), with the maturity score being higher in the obese group than in normal-weight subjects (Tukey's post-hoc test, P=0.004). The linear regression showed a positive association between BMI and the maturity score after adjusting for sex and age (β=0.34, P<0.001). The linear regression coefficient was higher in girls (β=0.61, P<0.001) than in boys (β=0.31, P=0.02).* ***Conclusions***: *These data suggest that dental maturation is positively associated with BMI in Korean children. Since many treatment decisions are made in relation to dental maturity, these findings may have implications for pediatric dental care.*

Keywords: *Dental development; Korean children; Childhood obesity; Body mass index*

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INTRODUCTION

Evaluating growth patterns in the pediatric age group is important for establishing long-term treatment plans or determining the prognosis of treatment[1]. The method for evaluating such growth and development can be roughly divided into the chronological age and the developmental age. However, even at the same chronological age, the body maturity varies with the biological age, which makes it inappropriate as an indicator of child development. The developmental age is considered more reliable for evaluating the maturational status of an individual[2]. Several growth assessment parameters such as skeletal development, sexual maturity, and dental development are used to determine the developmental age of children[3].

The increasing number of obese children due to dietary changes in modern societies has raised the question of whether there is a correlation between obesity and dental maturation. Childhood obesity has become a major public health problem worldwide[4], with more than 340 million children and adolescents of school age (5–19 years old) being overweight or obese in 2016 according to the World Health Organization (WHO)[5]. A recent worldwide study involving more than 31.5 million children and adolescents found that the increasing trend in the body mass index (BMI) of the pediatric population has stabilized in many high-income countries, albeit at high levels, while it had accelerated in parts of Asia[6].

Childhood obesity is also associated with maxillofacial and dental issues. Obese adolescents show changes in craniofacial morphology, with lengthened maxillaes and mandibles compared to normal-weight adolescents[7]. A study based on three cycles of the NHANES (National Health and Nutrition Examination Survey; 2001–2002, 2003–2004, and 2005–2006) found that obese children had significantly more permanent teeth erupted than nonobese children after adjusting for sex, age, and race[8]. On the other hand, an examination of the correlations of the timing of deciduous tooth emergence with weight and height revealed that weight showed a stronger association for canines, lateral incisors, and upper central incisors[9]. There have been many previous reports of an association between childhood obesity and dental caries[10].

While the relationship between obesity and dental age also has been examined, the definitive relationship remains controversial. A study involving a Hispanic population found that dental maturity was significantly more advanced in obese or overweight subjects than in underweight or average-weight subjects[11]. Another study found that dental development was significantly accelerated with increased BMI in children aged 8 to 15 years, even after adjusting for sex and age[12]. Conversely, no significant correlation between dental maturity and BMI was reported for children aged 6–14 years in Brazil[13] and 10–16 years in Peru[14]. However, no previous study has evaluated these correlations in an Asian population.

The purpose of this study was to identify the relationship between dental maturation and BMI in Korean children in order to facilitate the determination of optimal treatment plans, methods, timing, and prognoses in pediatric dentistry.

MATERIALS AND METHOD

Subjects

The protocol used in this retrospective study was reviewed and approved by the Institutional Review Board (IRB) of Yonsei University College of Dentistry (IRB number: 2-2016-0050). The study analyzed a sample of panoramic radiographs of Korean children aged between 5 and 10 years. The sample was obtained from patients who visited the Department of Pediatric Dentistry, Yonsei University Dental Hospital, Seoul, Korea between 2010 and 2017. In total, 600 participants comprising 50 boys and 50 girls in each of 6 age groups were randomly selected who met following criteria. The inclusion criteria were (1) pretreatment panoramic radiographs of adequate quality for diagnostic purposes, (2) height and weight recorded on the same day as when the panoramic radiographs were obtained, (3) aged at least 5 years but younger than 11 years at the time of the recording, and (4) all permanent teeth of the left mandible present (the presence of the third molar was not assessed). The exclusion criteria were (1) congenital anomalies of the permanent teeth of the left mandible (e.g., supernumerary tooth, delayed development, or taurodont molars), (2) permanent deciduous teeth that had undergone endodontic treatments, (3) any significant medical history that would affect the development or growth of teeth, or (4) experience of orthodontic treatment.

At the first appointment, height and weight were measured using a standard mechanical scale (DS-H01, Dong Sahn Jenix, Seoul, Korea) and recorded in the subject's electronic medical record by the dentist. The BMI values of the subjects were calculated from the height and weight data. Variability with sex and age was accounted for based on BMI percentile values from age- and sex-specific growth charts proposed by the CDC (Centers for Disease Control and Prevention)[15]. The children were divided into four groups of weight status based on BMI percentiles as recommended by the WHO: (1) underweight (<5th percentile), (2) normal weight (5th to <85th percentile), (3) overweight (85th to <95th percentile), and (4) obese (≥95th percentile).

Evaluation of dental maturity

Five lower-left permanent teeth (canine, first premolar, second premolar, first molar, and second molar) on panoramic radiographs were observed and rated according to the eight-stage scheme presented by Demirjian *et al* [16]. Central and lateral incisors were not rated since they do not appear clearly in panoramic radiographs (being overlapped by cervical vertebrae), which may affect the reliability of the results. The development of the roots and crowns of teeth was categorized into eight stages ranging from 'A' (least development) to 'H' (complete development). The stage of each tooth was converted into a score using the table suggested by Demirjian *et al*, and the sum of these scores for all five teeth was designated as the 'maturity score'[17].

Panoramic radiographs of each subject were reviewed by two pediatric dentists to determine the dental maturity stage. Each investigator examined 600 radiographs, and only those with the same results were accepted, with consensus reached by discussions where necessary. If the difference in score between the two investigators exceeded 2 points, the median was used as the final value. To evaluate the reproducibility of the evaluators, 30 radiographs were randomly selected and scored by the first examiner twice over an interval of 1 week. The same 30 radiographs were also scored by the other examiner after calibration. Cohen's kappa coefficient was 0.967 and 0.890 in the intra- and inter-observer reliability tests, respectively.

Statistical analysis

Analysis of variance (ANOVA) was performed to analyze the differences between the weight-status groups (underweight, normal weight, overweight, and obese) followed by Tukey's post-hoc test. Multiple linear regression adjusting for sex and age was used to determine the relationship between BMI and the dental maturity score. A linear regression model of the relationship between BMI and the dental maturity score was also applied with stratification for sex as well as for sex and age. A probability value of $P<0.05$ was considered significant in all statistical analyses, which were conducted using SAS (version 9.4, SAS Institute, Cary, NC, USA).

RESULTS

The distribution of the sample according to weight status for each sex is provided in Table 1. Approximately 2.50% of the total sample was underweight (n=15), 69.83% was normal weight (n=419), 12.33% was overweight (n=74), and 15.33% was obese (n=92). The proportion of those in the normal-weight group was lower for boys (62.00%) than for girls (77.67%).

This study found statistically significant differences in dental maturity between the weight groups (ANOVA, P=0.003). The mean maturity score was 57.27 (95% confidence interval

[CI]=50.55–64.00) for underweight subjects, 55.83 (95% CI=54.64–57.03) for normal-weight subjects, 58.85 (95% CI=50.39–61.31) for overweight subjects, and 60.56 (95% CI=58.42–62.70) for obese subjects. The maturity score was significantly higher in the obese group than in normal-weight subjects (Tukey's post-hoc test, P=0.004) (Figure 1).

The results from the linear regression model of the relationship between BMI and the dental maturity score are provided in Table 2. After adjusting for sex and age, a significant correlation was found between BMI and the maturity score (linear regression coefficient [β]=0.34, P<0.001). The linear regression coefficient (β) for the correlation between BMI and the dental maturity score was also statistically significant according to sex respectively, after adjusting for age (β=0.27 [P=0.04] in boys and β=0.58 [P<0.001] in girls).

Figure 2 shows the results from the linear regression model of the relationship between BMI and the dental maturity score according to sex and age. The value of β was statistically significant in 6- and 9-year-old boys and in 5-, 7-, and 8-year-old girls. The linear regression coefficient according to sex was highest in 6-year-old boys and 5-year-old girls, while β was not statistically significant in the other groups.

Table 1. Distribution of the weight status for each sex

International BMI category	Boys		Girls	
	n	(%)	*n*	(%)
Underweight	8	(2.67)	7	(2.33)
Normal weight	186	(62.00)	233	(77.67)
Overweight	37	(12.33)	37	(12.33)
Obese	69	(23.00)	23	(7.67)

BMI, body mass index

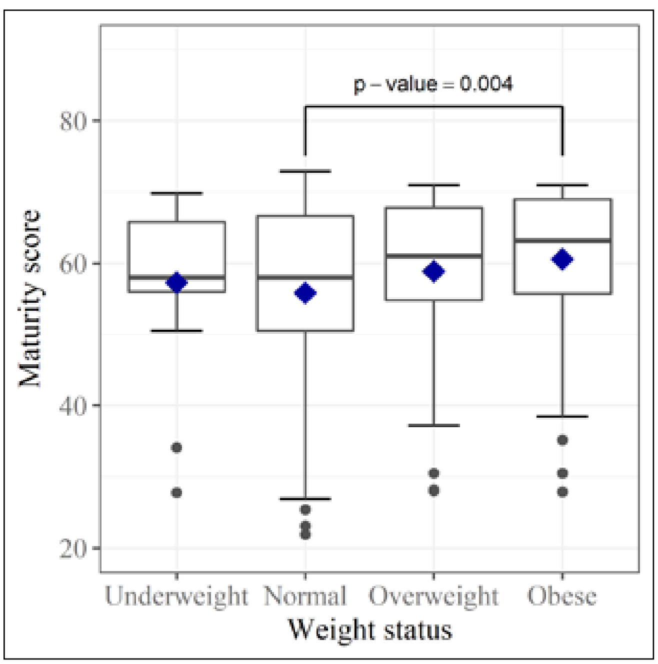

Figure 1. Box plot showing the distribution of maturity scores for each group. The only statistically significant difference was between the normal-weight and obese groups. Each diamond and bold line in the box indicates the mean and median of the maturity score. *P<0.05 in Tukey's post-hoc test.

Table 2. Results from the multiple linear regression model of the relationship between BMI and the dental maturity score

	β	SE	t	P
Male				
BMI	0.31	0.14	2.3	0.02
Age (months)	6.16	0.22	28.4	<0.001
Female				
BMI	0.61	0.15	4.01	<0.001
Age (months)	5.60	0.21	27.12	<0.001
Total				
BMI	0.44	0.10	4.4	<0.001
Age (months)	5.88	0.15	39.21	<0.001
Sex	1.93	0.49	3.95	<0.001

β, linear regression coefficient; SE, standard error

DISCUSSION

This study found that BMI was positively correlated with dental maturity in Korean children. While comparisons with previous studies are difficult since none of them involved a Korean population, the present findings are in general agreement with several previous studies. Akridge et al.[12] suggested that dental development was accelerated in children who had higher BMI after adjusting for sex and age. In the study conducted by Akridge[12], the difference between the dental age and chronological age was 0.63±1.31 years (mean±SD) in normal-weight subjects, 1.51±1.22 years in overweight subjects, and 1.53±1.28 years in obese subjects. A previous study involving Hispanics found that obese or overweight group had a significantly greater mean difference between chronologic and dental ages than did underweight or average group[11]. In our study, statistically significant differences in dental maturity were found between four weight groups (ANOVA, P=0.003). As shown in Figure 1, the maturity score was significantly higher in the obese group than in normal-weight subjects, which is consistent with the findings of these previous studies[11,12]. In contrast, previous studies involving children aged 6–14 years in Brazil[13] and 10–16 years in Peru[14] found no significant association between dental maturity and BMI. These contradictory results may be explained by the previous studies including older children compared to the present study, which only involved those aged 5–10 years. Racial differences could also have contributed to the differences.

This study found a positive correlation between dental development and BMI after adjusting for sex and age in a multiple linear regression model (β=0.44, P<0.001). In particular, the linear regression coefficient was higher in girls (β=0.61, P<0.001) than in boys (β=0.31, P=0.02). This finding supports that tooth development in girls is more affected by BMI, and is also consistent with previous observations[12] suggesting that dental development is more accelerated in girls when evaluating dental age differences according to sex. A similar study[17] found significant (but weak) correlations between BMI percentiles and the dental age (Pearson coefficient [γ]=0.227, P<0.01) as well as the cervical vertebral stage (γ=0.157, P<0.05). That study also demonstrated that as the BMI percentile increased by 1, the dental age difference increased by 0.008 years in a multiple

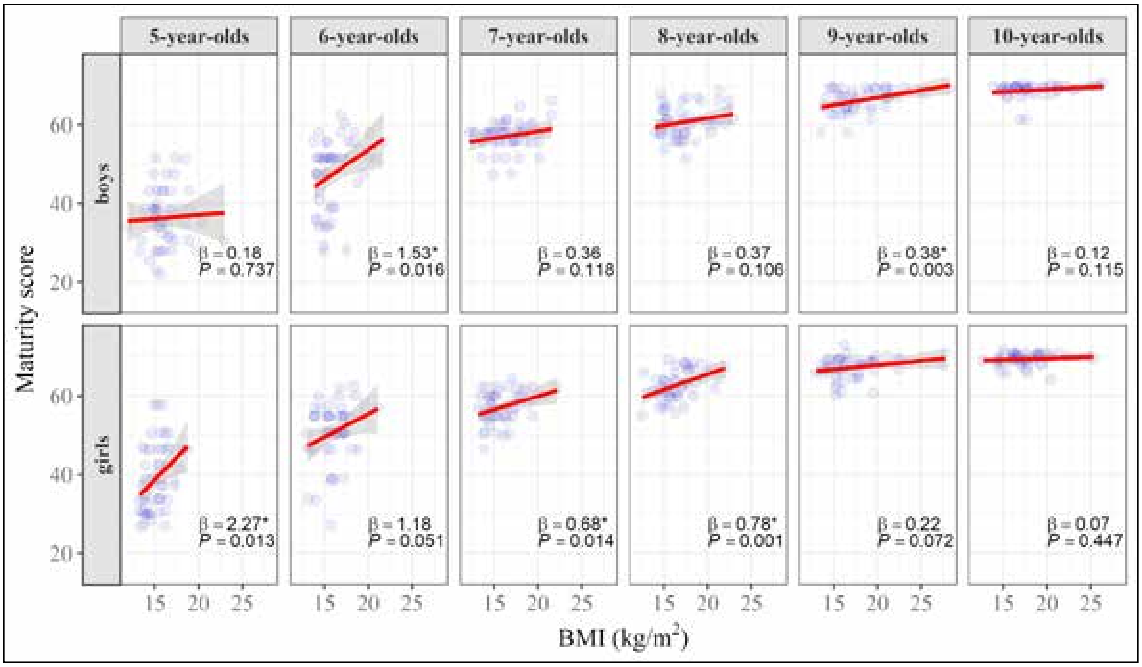

Figure 2. Results from the linear regression model of the relationship between BMI and the maturity score in each age group and sex. The linear regression coefficient (β) suggests the expected change in dental maturity score for a unit change in BMI. The bold line indicates the regression line and gray region indicates the 95% confidence interval of the regression line.

* β was statistically significant ($P<0.05$).

linear regression model. Race was a statistically significant explanatory variable, with dental development being accelerated in black children compared to white children.

When analyzed separately according to age and sex, some groups showed no statistically significant relationship between BMI and the maturity score (Figure 2), which might be related to age- and sex-related differences in tooth maturity; for example, tooth development was active in 5-year-old girls but not in 5-year-old boys. Sex differences in dental development have been well documented in other studies establishing that females in most populations exhibit more-advanced teeth formation and permanent teeth eruption than males[18,19]. Demirjian and Levesque also found that girls were more advanced than boys by 0.41 years (or 5 months) across all teeth[19]. It is particularly interesting to note that the linear regression coefficient peaked in different age groups for the two sexes (Figure 2), being highest in the 6-year-old group among boys (β=1.53) and in the 5-year-old group among girls (β=2.27). These results are also related to previous findings of sex differences in dental development. On the other hand, the linear regression coefficients became smaller and not statistically significant as age increased, which could be due to tooth development mostly being completed. For example, by the age of 10 years most of the teeth were in Demirjian stage H or G[16], showing similar tooth maturity scores regardless of BMI.

The distribution of the sample according to weight status for each sex is provided in Table 1. According to KNHANES III (The Third Korea National Health and Nutrition Examination Survey, 2005), the prevalence of obesity among Korean children and adolescents was 9.7% (11.3% for boys and 8.0% for girls), and had increased by 1.7-fold compared to 1997[20]. The proportion of those in the obese group was 15.3% in this study, which was higher than in the national survey. The results of the present study suggest that the prevalence of obesity among Korean juveniles is still increasing, and is higher than the prevalence of childhood obesity in the United States[21]. Studies involving children and adolescents have suggested that having a very high BMI increases the risk of chronic diseases in adulthood such as elevated blood pressure, abnormal glucose, and abnormal lipids[22]. Health-care providers therefore need to provide dietary education not only to promote oral health but also to maintain a healthy overall physical state.

The current study was subject to several limitations. First, this study included only a small cohort of underweight subjects, which might have been responsible for the dental maturity in the underweight group not differing significantly from that in the other groups (Figure 1). Further research with larger underweight cohorts is required to better evaluate the effect of low BMI and delayed dental development. Second, the Demirjian method has shortcomings. Dental maturity can be estimated based on tooth calcification and tooth eruption, with the latter considered inferior since it is influenced more by local and systemic factors[23]. The calcification grade of teeth is more suitable for evaluating their maturity because it is less influenced by the surrounding environment and a continuous series of maturation processes[24]. Many different methods have been suggested for estimating dental age using permanent tooth formation, among which the Demirjian method[16] is widely used because of its simplicity and being based on radiographic and schematic illustrations of tooth development. This method divides tooth formation into eight stages (A to H) according to the calcified point of each tooth. Demirjian also suggested that the dental maturity score can be converted directly into a dental age. However, many studies such as those conducted in the United Kingdom[25], New Zealand[26], and

South Korea[27] have shown that the Demirjian method overestimates the dental age. Lee et al. suggested that Willem's method was the most accurate method for estimating age in Korean juveniles and adolescents[27]. However, Willem's method may also overestimate dental age[28]. Since the present study focused on the tooth maturity score according to BMI rather than the difference between dental age and chronological age, the Demirjian method was considered acceptable. However, it would be beneficial to adopt another method if the same trend is found. Finally, no socioeconomic information on the subjects was available in this study. Many studies have demonstrated an association between socioeconomic status and the oral health or development of children[29,30]. Further studies, which take these variables into account, will need to be undertaken.

To the best of our knowledge, this is the first study to determine the association between obesity and dental maturity in a Korean pediatric population. Further studies are needed to examine the association between BMI and tooth development, since this may provide useful guidance for dental treatment. For example, obese children may require an early intervention of orthodontic treatment and more-conservative restoration of primary teeth, because they might experience tooth exfoliation earlier than in normal-weight children. Growth modification, the setting of space maintainers, and serial extraction also should be considered along with the weight status of children, since this is related to dental maturation. These findings may have implications for dental and orthodontic health care.

CONCLUSION

Dental maturity is positively correlated with BMI in Korean children. The effects of BMI on dental maturation differed according to sex and age, with tooth development being affected by BMI more in girls than in boys. Obese children are likely to have accelerated dental development compared to normal-weight children.

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