Predictive Value of Dental Maturity for a Positive Gonadotropin-Releasing Hormone Stimulation Test Result in Girls with Precocious Puberty

Jee-Seon Baik,1 Jin-Woo Choi,2 Su Jin Kim,3 Ji Hyun Kim,4 Sollip Kim,5 and Jae Hyun Kim6

1Department of Oral and Maxillofacial Surgery, Inje University College of Medicine, Ilsan Paik Hospital, Goyang, Korea; 2Department of Oral and Maxillofacial Radiology, Dankook University College of Dentistry, Cheonan, Korea; 3Department of Pediatrics, Myongji Hospital, Seonam University College of Medicine, Goyang, Korea; 4Department of Pediatrics, Dongguk University Ilsan Hospital, Goyang, Korea; 5Department of Laboratory Medicine, Inje University College of Medicine, Ilsan Paik Hospital, Goyang, Korea; 6Department of Pediatrics, Inje University College of Medicine, Ilsan Paik Hospital, Goyang, Korea

Received: 1 June 2016  Accepted: 2 November 2016

Address for Correspondence:
Jae Hyun Kim, MD
Department of Pediatrics, Inje University College of Medicine, Ilsan Paik Hospital, 170 Juhwa-ro, Ilsanseo-gu, Goyang 10380, Republic of Korea
E-mail: pedendo@paik.ac.kr

Funding: This study was supported by a grant from the Korean Society of Pediatric Endocrinology (2013).

INTRODUCTION

Central precocious puberty (CPP) is defined as the early development of secondary sexual characteristics (before the ages of 8 years in girls and 9 years in boys) (1,2). Accurate diagnosis and treatment of CPP are essential because it is associated with compromised adult height as well as psychosocial and behavioral problems (3,4). The gonadotropin-releasing hormone stimulation test (GnRHST) has been used as the gold standard for diagnosing CPP, as it confirms the hormonal activation of the hypothalamic-pituitary-gonadal axis (5-7). The GnRHST could be inconvenient for both patients and clinicians because of repeated samples over 1 to 2 hours. Moreover, approximately 30% of individuals suspected with precocious puberty showed prepubertal response during the GnRHST (8,9). Therefore, it is important to accurately select patients who are expected to have a positive response during the GnRHST.

Skeletal maturity is assessed using bone age (BA), which is determined based on findings from the left hand and wrist radiographs (10,11). BA is an essential part of the initial evaluation for pubertal disorders, as advanced BA is related to early exposure of sex hormones (12). Dental developments and maturity have been used to assess skeletal maturity after the development of a new dental age assessment by Demirjian et al. (13). In this context, dental maturity was assessed using morphological differences in the calcification stages of the mandibular canine, second premolar, second molar, or third molar (14,15), and several studies have reported strong correlation between skeletal and dental maturity (16-18). Dental maturity is affected by several diseases and conditions. Patients with juvenile rheumatoid arthritis showed advanced dental maturity (19). In contrast, dental development is retarded in patients with constitutional delay in growth and puberty (20). However, only a few case studies have evaluated dental maturity in patients with precocious puberty (21).

The present study aimed to investigate the dental maturity of...
prepubertal girls and girls with CPP using data regarding the calcification stages of the mandibular second premolar and molar, to evaluate the usefulness of dental maturity as a screening test for CPP, and to identify anthropometric and laboratory factors affecting dental maturity and predictors of the pubertal response during the GnRHST.

MATERIALS AND METHODS

Participants
All girls who visited our pediatric endocrinology clinics between November 2013 and January 2015 were considered for participation in the study. Study participants were enrolled prospectively. A case-control study design was used.

The inclusion criteria were as follows: breast development of Tanner stage 2 or higher before 8 years of age, advanced BA (at least a 1-year difference between BA and chronological age [CA]), and have undergone the GnRHST between the ages 7.0 years and 8.9 years. Among them, participants with peak luteinizing hormone (LH) ≥ 5 IU/L and < 5 IU/L after the GnRHST were classified into the pubertal and prepubertal groups, respectively. The exclusion criteria were as follows: peripheral precocious puberty, precocious puberty caused by organic brain lesion, chronic endocrinologic disorders, oral or maxillofacial anomalies, orthodontic treatment, or permanent extraction of teeth. The control group included girls aged 7.0–8.9 years without any secondary sexual characteristics. Subjects with basal LH ≥ 0.3 IU/L, BA advancement of ≥ 3 years (11), oral or maxillofacial anomalies, who had undergone orthodontic treatment, or who had had permanent teeth extracted, were not included in the control group.

Methods
From all study participants, clinical data, such CA, BA, height, weight and body mass index (BMI) were collected. Height and BMI were expressed as the standard deviation score (SDS), based on the 2007 Korean National Growth Charts (22). In the pubertal and prepubertal groups, laboratory data were obtained during the GnRHST. In the control group, fasting serum samples were used to measure the levels of LH, follicular stimulating hormone (FSH), estradiol, dehydroepiandrosterone sulfate (DHEAS), insulin-like growth factor-I (IGF-I), the IGF binding protein-3 (IGFBP-3), and 25-hydroxyvitamin D3 (25[OH]D3).

The GnRHST was conducted during the morning after an overnight fasting. Intravenous injection of 100 μg of GnRH (Relefact; Sanofi-Aventis, Frankfurt, Germany) was administered after obtaining basal serum samples. Blood samples were also collected at 30, 45, 60, and 90 minutes after GnRH administration. BA was evaluated by a single pediatric endocrinologist (JHK) using the Tanner-Whitehouse 3 methods (11).

Panoramic radiographs were obtained for all participants. Dental maturity was assessed according to the tooth calcification stages developed by Demirjian et al. (13). The characteristics of each stage according to Demirjian index (DI) (Fig. 1) were as follows (23): (A) Calcification of the occlusal points without fusion can be observed; (B) Fusion of the calcified points forms the occlusal surface; (C) Enamel formation at the occlusal sur-

![Fig. 1. Schematic illustration of the DI for dental maturity (13). DI = Demirjian index.](https://doi.org/10.3346/jkms.2017.32.2.296)
face is complete, dentin formation is observed, the pulp chamber has a curved shape, and no pulp horns are visible; (D) Crown formation is complete to the level of cemento-enamel junction, root formation is observed, the pulp horns are visible, and the walls of the pulp chamber are curved to the cervical region; (E) The walls of the pulp chamber are straight, the root length is less than the crown height, and radicular bifurcation is observed in the molar; (F) The walls of the pulp chamber form an isosceles triangle and the apex ends in a funnel shape, the root length is equal to or longer than the crown height, bifurcation has developed to give the roots a more definite form; (G) The walls of the root canal are parallel and its apical end is partially open; and (H) The apical end of the root canal is complete and the periodontal membrane is distinct. A dental radiologist (JWC) interpreted the panoramic radiographs of the mandibular second premolar and molar as one of 8 stages (A to H). The higher DI was assigned when a discrepancy between the left and right teeth was observed. Most participants exhibited nearly identical DI values for the right and left sides. To validate the reproducibility of the dental maturity index, the DI values were re-evaluated by the same dental radiologist (JWC) in 20 randomly selected subjects at 2 weeks after the initial evaluation.

Statistical analysis

Statistical analyses were performed using the Stata software (version 14.1; StataCorp LP, College Station, TX, USA). Kruskal-Wallis analysis was applied to continuous variables among the pubertal, prepubertal, and control groups. Post-hoc analysis was performed using the Mann-Whitney U test with a correction of type 1 error by Bonferroni’s method. Categorical variables were compared using the χ² test and P for trend. Logistic regression analysis was performed to identify factors predicting positive GnRHST results. The kappa statistics was applied for intra-observer agreement of DI. Data are expressed as median (interquartile range) or as odds ratios (ORs) and 95% confidence intervals (CIs). P values < 0.05 were considered statistically significant.

Ethics statement

Our study was approved by the Institutional Review Board of Ilsan Paik Hospital (IB-3-1305-021). Informed consent was obtained from patients and their legal guardians. All procedures were performed in accordance with the Declaration of Helsinki.

RESULTS

Clinical characteristics of study participants

A total of 103 participants (pubertal, 40; prepubertal, 19; and control, 44) were enrolled in the study. CA was not significantly different among the 3 groups. BA and the difference between BA and CA were significantly lower in the control group compared to other groups (P < 0.001; Table 1). No significant differences were observed in the anthropometric measurements, including height SDS, BMI SDS, and waist-to-height ratio (WHR) among groups.

Basal LH and FSH concentrations were significantly high in the pubertal group. Basal estradiol level was significantly different between the pubertal and control groups. In participants

| Table 1. Clinical characteristics of enrolled subjects at baseline |
|------------------|------------------|------------------|
| Variables          | Pubertal response (n = 40) | Prepubertal response (n = 19) | Control (n = 44) | P value |
| CA, yr             | 8.2 (7.8, 8.5)     | 8.1 (7.6, 8.5)     | 7.8 (7.5, 8.3) | 0.058 |
| BA, yr             | 10.0 (9.7, 10.3)   | 9.9 (9.6, 10.2)   | 8.4 (7.1, 9.3) | < 0.001 |
| BA advancement, yr | 1.8 (1.5, 2.5)    | 1.6 (1.5, 2.2)    | 0.6 (−0.6, 1.3) | < 0.001 |
| Height SDS         | 0.9 (0.5, 1.4)    | 0.8 (0.4, 1.4)    | 0.5 (−0.2, 1.3) | 0.067 |
| BMI SDS            | 0.8 (0.3, 1.4)    | 0.8 (0.2, 1.4)    | 0.4 (−0.4, 1.1) | 0.052 |
| Overweight and obesity, No. (%) | 18 (45.0%) | 7 (36.8%) | 13 (29.6%) | 0.341 |
| Basal LH, IU/L     | 0.3 (0.0, 1.0)†   | 0.0 (0.0, 0.0)†   | 0.0 (0.0, 0.0)† | < 0.001 |
| Basal FSH, IU/L    | 2.9 (1.9, 4.0)†   | 1.6 (1.0, 2.6)†   | 1.7 (1.3, 2.4)† | < 0.001 |
| Basal estradiol, pg/mL | 7.1 (2.5, 16.6)† | 2.5 (2.5, 8.3)†  | 2.5 (2.5, 6.7)† | 0.041 |
| Peak LH, IU/L      | 9.7 (7.6, 13.5)   | 3.5 (2.5, 4.3)    | - | < 0.001 |
| Peak FSH, IU/L     | 12.4 (10.5, 15.4) | 8.8 (5.7, 11.8)   | - | < 0.001 |
| DHEA-S, μg/dL      | 42.5 (29.6, 59.6) | 45.0 (28.8, 54.4) | 48.6 (29.7, 79.5) | 0.389 |
| 25(OH)D3, ng/mL    | 17.8 (13.8, 22.5)† | 16.7 (14.1, 22.0)† | 23.9 (20.0, 27.2)† | < 0.001 |
| IGFI, ng/mL        | 301.5 (252.2, 343.4)† | 272.7 (212.0, 297.2)† | 203.2 (157.0, 254.0)† | < 0.001 |
| IGFBP-3, ng/mL     | 4,770 (4,195, 5,365) | 4,710 (4,050, 5,710) | 4,675 (4,285, 5,035) | 0.830 |
| DI of the mandibular second premolar (C/D/E/F) | 0/4/36/0 | 1/7/11/0 | 1/22/21/0 | 0.001 |
| DI of the mandibular second molar (C/D/E/F) | 0/19/19/2 | 2/12/5/0 | 6/32/6/0 | 0.004 |

Values are presented as median (interquartile range); Data were analyzed using the Kruskal-Wallis test. The post-hoc analysis was performed using the Mann-Whitney U test with Bonferroni’s method. Peak LH and FSH levels were analyzed using the Mann-Whitney U test with a correction of type 1 error by Bonferroni’s method. Categorical variables were compared using the χ² test and P for trend. Logistic regression analysis was performed to identify factors predicting positive GnRHST results. The kappa statistics was applied for intra-observer agreement of DI. Data are expressed as median (interquartile range) or as odds ratios (ORs) and 95% confidence intervals (CIs). P values < 0.05 were considered statistically significant.

*†, ‡Superscripts indicate significant differences between values with the same marks.
who underwent the GnRHST, peak LH and FSH levels were high in the pubertal group \( P < 0.001 \). The 25(OH)D3 concentrations were observed to be the highest in the control group \( P < 0.001 \); however, there were no differences between the pubertal and prepubertal groups. IGF-I concentrations were the highest in the pubertal group and the lowest in the control group \( P < 0.001 \), but the IGFBP-3 levels were not different among groups \( P = 0.830 \).

**Dental development of study participants**

The reproducibility of the DI was almost perfect (24). The kappa coefficient for intra-observer agreement was 0.854 for the second mandibular premolar and 0.811 for the second mandibular molar.

The DI of the mandibular second premolar and molar was distributed from stage C to F (Table 1, Fig. 2). The distribution of the maturation stage of the mandibular second premolar and molar was significantly different among groups \( P = 0.001 \) and \( P = 0.038 \), respectively); a higher DI was observed in the pubertal group (Table 1).

CA, BA, BA advancement, height SDS, peak LH after the GnRHST, and IGF-I were associated with an increased DI in both the mandibular second premolar and molar (Table 2, Fig. 3). BMI SDS and overweight and obesity were associated with a DI value of \( \geq E \) for the mandibular second premolar. The basal FSH level was associated with an increased DI for the mandibular second molar.

**Logistic regression analysis for determining predictors of pubertal response in the GnRHST**

The control group was considered as the prepubertal group with a prepubertal response in the GnRHST when logistic regression analysis was performed. CA, BA, difference between BA and CA, and levels of basal LH, basal FSH, basal estradiol, 25(OH) D3, and IGF-I were predictors associated with positive GnRHST results (data not shown). A DI value of \( \geq E \) for both the mandibular second premolar and molar was a significant predictor of pubertal response in the GnRHST. The OR of the second premolar and molar was 8.7 (95% CI, 2.9–26.1) and 5.2 (95% CI, 2.2–12.7), respectively (Table 3). The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for predicting a positive response in the GnRHST for a DI value of \( \geq E \) were 90.0%, 49.2%, 52.9%, and 88.6%, respectively, for the mandibular second premolar and 52.5%, 82.5%, 65.6%, and 73.2%, respectively, for the mandibular second molar (Table 3).

**DISCUSSION**

In the present study, we observed that dental maturity, as assessed by the DI, was a useful marker for predicting a positive response in the GnRHST. A DI value of \( \geq E \) for the mandibular second premolar and molar was a significant predictor of a positive response in the GnRHST in girls suspected to have CPP in

---

**Table 2. Factors affecting dental maturity of the mandibular second premolar and molar (a DI value of \( \geq E \))**

| Variables                  | Mandibular second premolar | Mandibular second molar |
|----------------------------|-----------------------------|-------------------------|
|                            | OR  | 95% CI | \( P \) value | OR  | 95% CI | \( P \) value |
| CA, yr                     | 5.2 | 2.0, 13.4 | < 0.001       | 3.1 | 1.2, 7.7 | 0.012           |
| BA, yr                     | 2.7 | 1.7, 4.1 | < 0.001       | 3.0 | 1.7, 5.6 | < 0.001         |
| BA advancement, yr         | 2.1 | 1.4, 3.2 | < 0.001       | 2.3 | 1.4, 3.7 | < 0.001         |
| Height SDS                 | 2.1 | 2.0, 13.7 | < 0.001       | 3.1 | 1.2, 7.7 | 0.012           |
| BMI SDS                    | 2.1 | 1.4, 3.6 | 0.002         | 3.0 | 1.7, 5.6 | < 0.001         |
| Overweight and obesity     | 5.7 | 2.0, 13.7 | < 0.001       | 3.1 | 1.2, 7.7 | 0.012           |
| Basal LH, IU/L             | 3.3 | 0.9, 12.2 | 0.084         | 3.0 | 1.7, 5.6 | < 0.001         |
| Basal FSH, IU/L            | 3.2 | 1.0, 10.0 | \( P \) value | 3.0 | 1.7, 5.6 | < 0.001         |
| Basal estradiol, pg/mL     | 1.0 | 1.0, 1.0 | 0.894         | 1.0 | 1.0, 1.0 | 0.386           |
| Peak LH, IU/L              | 1.0 | 1.0, 1.0 | 0.034         | 1.1 | 1.0, 1.3 | 0.014           |
| Peak FSH, IU/L             | 1.1 | 1.0, 1.4 | 0.113         | 1.1 | 1.0, 1.3 | 0.061           |
| IGF-I, ng/mL               | 1.0 | 1.0, 1.0 | 0.002         | 1.0 | 1.0, 1.0 | 0.009           |

DI = Demirjian index, OR = odds ratio, CI = confidence interval, CA = chronological age, BA = bone age, SDS = standard deviation score, BMI = body mass index, LH = luteinizing hormone, FSH = follicular stimulating hormone, IGF-I = insulin-like growth factor-I.
Table 3. Diagnostic performance of the dental maturity at the mandibular second premolar and molar according to DI for the GnRHST result

| Predictors                  | DI    | Pubertal response in the GnRHST, No. (%) | OR (95% CI) | Sensitivity, % | Specificity, % | PPV, % | NPV, % |
|-----------------------------|-------|------------------------------------------|-------------|----------------|----------------|--------|--------|
| Mandibular premolar         | ≤ D   | 32 (50.8)                                | 8.7 (2.9, 26.1) | 90.0           | 49.2           | 52.9   | 88.6   |
|                             | ≥ E   | 36 (90.0)                                |             |                |                |        |        |
| Mandibular second molar     | ≤ D   | 11 (17.5)                                | 5.2 (2.2, 12.7) | 52.5           | 82.5           | 65.6   | 73.2   |
|                             | ≥ E   | 21 (52.5)                                |             |                |                |        |        |

DI = Demirjian index, GnRHST = gonadotropin-releasing hormone stimulation test, OR = odds ratio, CI = confidence interval, PPV = positive predictive value, NPV = negative predictive value.
this study. The OR of the mandibular second premolar and mol-
lar (a DI value of ≥ E) was 8.7 (95% CI, 2.9–26.1) and 5.2 (95% CI, 2.2–12.7), respectively. The mandibular second premolar with a DI value of ≥ E had a sensitivity of 90.0%. The mandibular second molar with a DI value of ≥ E showed a specificity of 82.5%. Dental development of both teeth was a useful indicator for diagnosing CPP. Moreover, a DI value of ≤ C for the mandibular second premolar and molar showed an NPV of 100.0% for the positive response of GnRHST. A DI value of ≥ F for the mandibular second molar showed a PPV of 100% for the pubertal response in the GnRHST.

In the clinical setting, dental maturity might be a useful screening tool when the decision regarding whether to perform the GnRHST confirmatory test for CPP is equivocal, based on the patient’s clinical presentation and given that GnRHST is a time-consuming procedure requiring repeated samples. Dentists could relatively easily refer girls with advanced DI and pubertal signs to a pediatrician for further evaluation.

Previous researchers have reported that dental maturity is associated with CA and BA (16–18,25). In this study, we revealed that a higher DI value was associated with higher CA, BA, and difference between BA and CA. Costacurta et al. (26) reported that dental development was related to body adiposity among children. Obese children with higher body fat showed accelerated skeletal–dental age. In this study, BMI SDS, abdominal obesity, and WHR showed a positive association with higher DI values of the mandibular second premolar.

In the present study, dental maturity was assessed using the DI because it is reported as a reliable indicator of skeletal maturity (18,27). Moreover, using the DI is advantageous because the maturation stage can be classified based on the crown-to-root ratio of the tooth rather than the absolute length; furthermore, magnification errors related to panoramic radiographs can be eliminated. In this study, a DI value of ≥ E indicated a high predictive value for diagnosing CPP. In panoramic radiographs, it is not difficult to distinguish between DI stages of D and E because the existence of a straight pulpal wall and bifurcation in the second molar is a distinct feature of stage E (13).

In panoramic radiographs, there is a superimposition of the palatal root and anatomic structures (e.g., the palate, zygomatic arch, or the inferior nasal concha), which makes it difficult to observe the roots. Thus, previous researchers generally evaluated dental maturity of the mandibular canine, second molar, or third molars (15,16,18). However, we used the mandibular second premolar and molar for evaluating dental maturity in this study. The reasons for this were as follows: 1) roots of the mandibular anterior tooth intermittently overlapped with the ghost image of the cervical vertebrae on the panoramic radiographs; 2) the third molars are commonly missing in humans; and 3) the third molars cannot be clearly visualized in children who are less than 7 or 8 years old.

Panoramic radiographs visualize both jaws and their dentition continuously by a rapid, simple, and convenient procedure. Owing to these advantages, panoramic radiography has been widely used in screening for dental disorders and epidemiologic studies (28). Compared to the GnRHST, dental maturity can be examined easily during routine dental examination with panoramic radiography. The effective dose for panoramic radiography was reported to range from 14 to 24 μSv, which is equivalent of 2 to 3 days of additional background radiation exposure (29,30).

According to previous studies, the predictors of a positive Gn-RHST were basal LH levels, basal FSH levels, previous height velocity, 25(OH)D3 levels, BA, BA advancement, and IGF-I levels (8,9,31). Houk et al. (32) suggested that the unstimulated LH level using the third generation assay was adequate for diagnosing CPP in most cases. Nam et al. (9) reported that rapid growth velocity with a cut-off value of 3.8 cm over 6 months was a useful marker for predicting CPP in participants who have undergone the GnRHST. Lee et al. (31) showed the possibility of an association between CPP and lower 25(OH)D3 concentrations. Similarly, in the present study, the positive GnRHST response was associated with BA, the difference between BA and CA, and levels of basal LH, basal FSH, basal estradiol, 25(OH)D3, and IGF-I.

This study has several limitations. First, the number of enrolled participants was insufficient. Second, this study was performed only in girls because cases of CPP were relatively rare among boys. Third, the DI value determined based on panoramic radiograph findings might vary depending on the dental radiologists. Fourth, dental maturity might also be affected by other genetic, ethnic, nutritional, and environmental factors, which were not analyzed in this study (33,34). However, to the best of our knowledge, this is the first study to use an age-matched control group to validate the usefulness of dental maturity for predicting a diagnosis of CPP.

In conclusion, dental maturity assessed using the DI is a strong predictor for diagnosing CPP using the GnRHST. The OR of the mandibular second premolar and molar (a DI value of ≥ E) is 8.7 and 5.2, respectively. Furthermore, dental maturity is associated with BA, CA, BA advancement, and obesity. Therefore, evaluating dental maturity in girls who are suspected of having precocious puberty may help determine whether they should undergo the GnRHST.

DISCLOSURE

The authors have no potential conflicts of interest to disclose.

AUTHOR CONTRIBUTION

Conceptualization: Kim JH. Data curation: Kim SJ, Kim JH, Kim JH. Formal analysis: Kim JH. Funding acquisition: Kim JH. In-
vestigation: Baik JS, Choi JW, Kim S, Kim JH. Writing - original draft: Baik JS, Choi JW, Kim JH. Writing - review & editing: Kim SJ, Kim JH, Kim S.

ORCID

Jae Hyun Kim http://orcid.org/0000-0002-0203-7443
Sollip Kim http://orcid.org/0000-0003-0474-5897
Ji Hyun Kim http://orcid.org/0000-0001-5489-1169
Su Jin Kim http://orcid.org/0000-0003-0893-0512

REFERENCES

1. Lee PA. Central precocious puberty. An overview of diagnosis, treatment, and outcome. Endocrinol Metab Clin North Am 1999; 28: 901-18.
2. Carel JC, Léger J. Clinical practice. Precocious puberty. N Engl J Med 2008; 358: 2366-77.
3. Brauner R, Adan L, Malandy F, Zantieff D. Adult height in girls with idiopathic true precocious puberty. J Clin Endocrinol Metab 1994; 79: 415-20.
4. Mrug S, Elliott M, Gillland MJ, Grunbaum JA, Tortolero SR, Cuccaro P, Schuster M. Positive parenting and early puberty in girls: protective effects against aggressive behavior. Arch Pediatr Adolesc Med 2008; 162: 781-6.
5. Lee PA. Laboratory monitoring of children with precocious puberty. Arch Pediatr Adolesc Med 1994; 148: 369-76.
6. Brito VN, Batista MC, Borges MF, Lateronic AC, Kohek MB, Thirone AC, Jorge BH, Arnhold II, Mendonca BB. Diagnostic value of fluorometric assays in the evaluation of precocious puberty. J Clin Endocrinol Metab 1999; 84: 3539-44.
7. Resende EA, Lara BH, Reis JD, Ferreira BP, Pereira GA, Borges MF. Assessment of basal and gonadotropin-releasing hormone-stimulated gonadotropins by immunochemiluminometric and immunofluorometric assays in normal children. J Clin Endocrinol Metab 2007; 92: 1424-9.
8. Lee DS, Ryoo NY, Lee SH, Kim S, Kim JH. Basal luteinizing hormone and follicular stimulating hormone in girls with suspected precocious puberty in children of different ethnic origins: international maturity curves for clinical use. J Korean Med Sci 2009; 24: 1305-10.
9. Nam HK, Rhie YL, Son CS, Park SH, Lee KH. Factors to predict positive results of gonadotropin releasing hormone stimulation test in girls with suspected precocious puberty. J Korean Med Sci 2012; 27: 194-9.
10. Greulich WW, Pyle SI. Radiographic Atlas of Skeletal Development of the Hand and Wrist, 2nd ed. Stanford, CA: Stanford University Press, 1959.
11. Tanner JM. Assessment of Skeletal Maturity and Prediction of Adult Height (TW3 Method). 3rd ed. London: W.B. Saunders, 2001.
12. Martin DD, Wit JM, Hochberg Z, van Rijn RR, Fricke O, Werther G, Cameron N, Hertel T, Wudy SA, Butler G, et al. The use of bone age in clinical practice - part 2. Horm Res Pediatr 2011; 76: 10-6.
13. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973; 45: 211-27.
14. Morris JM, Park JW. Correlation of dental maturity with skeletal maturity from radiographic assessment: a review. J Clin Pediatr Dent 2012; 36: 309-14.
15. Lewis JM, Senn DR. Dental age estimation utilizing third molar development: a review of principles, methods, and population studies used in the United States. Forensic Sci Int 2010; 201: 79-83.
16. Cho SM, Hwang CJ. Skeletal maturation evaluation using mandibular third molar development in adolescents. Korean J Orthod 2009; 39: 120-9.
17. Perinetti G, Contardo L, Gabrieli P, Baccetti T, Di Lenarda R. Diagnostic performance of dental maturity for identification of skeletal maturation phase. Eur J Orthod 2012; 34: 87-92.
18. Kumar S, Singla A, Sharma B, Virdi MS, Anupam A, Mittal B. Skeletal maturation evaluation using mandibular second molar calcification stages. Angle Orthod 2012; 82: 501-6.
19. Lehtinen A, Oksa T, Helenius H, Rönnin O. Advanced dental maturity in children with juvenile rheumatoid arthritis. Eur J Oral Sci 2000; 108: 184-8.
20. Gaethofs M, Verdonck A, Carels C, de Zegher F. Delayed dental age in boys with constitutionally delayed puberty. Eur J Orthod 1999; 21: 711-5.
21. Roberts MW, Li SH, Comite E, Hench KD. Pescovitz OH, Cutler GB Jr, Loiriaux DL. Dental development in precocious puberty. J Dent Res 1985; 64: 1064-8.
22. Moon JS, Lee SY, Nam CM, Choi JM, Choe BK, Seo JW, Oh K, Kang MJ, Hwang SS, Yoo MH, et al. 2007 Korean national growth charts: review of developmental process and an outlook. Korean J Pediatr 2008; 51: 1-25.
23. Almeida MS, Pontual AA, Beltrão RT, Beltrão RV, Pontual ML. The chronology of second molar development in Brazilians and its application to forensic age estimation. Imaging Sci Dent 2013; 43: 1-6.
24. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977; 33: 159-74.
25. Maber M, Liversadge HM, Hector MP. Accuracy of age estimation of radiographic methods using developing teeth. Forensic Sci Int 2006; 159 Suppl 1: S68-73.
26. Costacurta M, Sicuro L, Di Renzo L, Condò R, De Lorenzo A, Docimo R. Childhood obesity and skeletal-dental maturity. Eur J Paediatr Dent 2012; 13: 128-32.
27. Goyal S, Goyal S, Gugnani N. Assessment of skeletal maturity using mandibular second molar maturation stages. J Clin Pediatr Dent 2014; 39: 79-84.
28. Choi JW. Assessment of panoramic radiography as a national oral examination tool: review of the literature. Imaging Sci Dent 2011; 41: 1-6.
29. Ludlow JB, Davies-Ludlow LE, White SC. Patient risk related to common dental radiographic examinations: the impact of 2007 International Commission on Radiological Protection recommendations regarding dose calculation. J Am Dent Assoc 2008; 139: 1237-43.
30. Kim EK. Effective dose of cone-beam computed tomography for orthodontic analysis in pediatric patient. J Korean Dent Assoc 2015; 53: 558-68.
31. Lee HS, Kim YJ, Shim YS, Jeong HR, Kwon E, Hwang JS. Associations between serum vitamin D levels and precocious puberty in girls. Ann Pediatr Endocrinol Metab 2014; 19: 91-5.
32. Houk CP, Kunselman AR, Lee PA. Adequacy of a single unstimulated luteinizing hormone level to diagnose central precocious puberty in girls. J Pediatr Adolesc Med 2006; 20: S68-73.
33. Chaillot N, Nyström M, Demirjian A. Comparison of dental maturity in children of different ethnic origins: international maturity curves for clinicians. J Forensic Sci 2005; 50: 1164-74.
34. Panchbhai AS. Dental radiographic indicators, a key to age estimation. Dentomaxillofac Radiol 2011; 40: 199-212.