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ORIGINAL RESEARCH

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Criteria for early diagnosis of congenitally missing second premolars based on the calcification grades of other permanent posterior teeth: a retrospective study

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Abstract

Diagnosing congenitally missing second premolars (SPs) in early childhood is challenging due to variations in their calcification ages. In this study, we investigated the correlation between calcification grades of SPs and other permanent posterior teeth to aid clinicians in the early diagnosis of congenitally missing SPs. This cohort study retrospectively evaluated 6813 images from 9261 panoramic image records of children aged 42–78 months. The Nolla method was used to score calcification grades of first and SP and first and second permanent molars. Images were divided into 6 subgroups based on age with six-month intervals, and average calcification grades of teeth were analyzed by gender and categorized. The calcification grades of these relevant teeth were separately analyzed, specifically for Grade 0 and Grade 1 for SPs. Gender-based analysis revealed statistically significant differences in the calcification grades of 4 first premolars, 4 permanent first molars, and 2 permanent second molars. However, these differences were not significant for all 4 SPs and teeth numbered 17 and 27 between genders. Generally, Nolla grades were higher in girls compared to boys, except for all 4 SPs and tooth numbered 46. Furthermore, higher Nolla grades were observed in older age groups, which was consistent with expectations. The variability in calcification grades of SPs highlights the importance of understanding the calcification grades of other permanent teeth, which are more clearly visible on radiological images of young children. This knowledge could help clinicians in assessing the dental maturity of pediatric patients and facilitate early diagnosis of congenitally missing teeth.

Keywords

Congenitally missing teeth; Second premolars; Children; Nolla method; Calcification grades

1. Introduction

Congenitally missing teeth represent the most prevalent dental anomaly in permanent dentition [1], frequently observed at the mandibular second premolars (SP), maxillary laterals, and maxillary SPs [2]. This condition can lead to dental mal-positioning, periodontal damage, insufficient development of maxillary and mandibular bone height, and adverse impacts on esthetics, function and overall quality of life [3].

Dental agenesis necessitates expensive and comprehensive treatments. Early diagnosis of congenital absence can guide treatment planning for edentulous spaces, which may involve leaving them open for prosthetic restoration or closing them through orthodontic interventions. Therefore, diagnosing congenitally missing teeth at the earliest stages is important for informing caregivers and facilitating the development of the most accurate treatment plan, which typically involves an interdisciplinary approach involving specialists in pediatric dentistry, oral and maxillofacial surgery, operative dentistry, orthodontics and prosthodontics.

In pediatric dentistry and orthodontics, dental age and chronological age do not always coincide. Dental/skeletal age typically receives more emphasis in these fields. Tooth eruption dates serve as a method for determining dental age [4]. However, this method is not applicable between the ages of 3–6 years and beyond 13 years. Moreover, delayed tooth eruption is another factor that warrants consideration [5]. Thus, radiographic examination becomes imperative for accurate dental age estimation.

In the literature, various radiological methods have been documented for dental age estimation, including the Schour and Masseler method (1941), Nolla's method (1960), Moorees, Fanning and Hunt method (1963), Stages by Kraus and Jordan (1965), and Demirjian, Goldstein and Tanner (1973). These methods are simple, non-invasive, and reproducible, utilizing tooth shapes on X-ray images from the initial stages of calcification to the final mature form [3]. Radiological assessment of the presence or absence of SPs poses greater difficulty

compared to evaluating other permanent teeth during early childhood. This challenge arises because SPs initially appear as small calcified areas, often obscured by the roots of primary molars and adjacent permanent tooth germs, particularly in the early stages of mineralization (see Fig. 1). SPs are recognized for exhibiting the most common variations in development and calcification. Although it is recommended to wait until the age of 3 years to decide on the congenital deficiency of the second premolar teeth, their calcification typically begins around 2–2.5 years of age, and delayed calcification is a frequently observed phenomenon in this dental group [6, 7].

Providing data regarding the calcification grades of permanent teeth with clear appearances in radiological images can enhance the understanding of dental maturity in pediatric patients and aid in the early detection of congenitally missing second premolar teeth. Therefore, the aim of this study is to establish criteria for the early diagnosis of congenitally missing SPs by examining the calcification grades of other permanent posterior teeth, including first premolars and permanent first and second molars.

2. Materials and methods

In this retrospective study, we retrieved and assessed the demographic data and panoramic radiographs of 9261 children aged between 42 and 78 months who visited the Department of Pediatric Dentistry Clinic at Bezmialem Vakif University between January 2014 and October 2020. The digital panoramic radiographs were obtained using a Planmeca Promax device (Planmeca, Helsinki, Finland; license number: 5701-002-KB-4-L) and protective lead aprons and neck collars, following which the images were recorded and stored in the Planmeca Romexis digital archive system.

The inclusion criteria for this study were panoramic radiographs (PRs) obtained from children aged between 42–78 months and PRs taken from children with no history of tooth extraction, orthodontic treatment, or syndromes that could impact tooth and bone development, such as Crouzon syndrome, Ectodermal dysplasia, or cleft lip and palate. Exclusion criteria included repetitive PR recordings from the same children, PRs with artifacts (such as various X-ray distortions and superpositions), and PRs obtained from children with developmental dental anomalies, excluding cases of hypodontia.

The X-ray images were examined using computers equipped with an 18.5-inch screen, a screen resolution of 1366 × 768, a 64-bit operating system, and a 64-based processor by 2 pediatric dentists. Calcification grades of posterior permanent teeth (including the first and SPs and the first and second permanent molars) in the upper and lower jaws were assessed on dental panoramic X-rays using the Nolla method. The Nolla method delineates 10 dental development stages, effectively representing the continuous progression of tooth development. However, it relies on subjective estimation to predict the length of the future crown or root. Previous studies have highlighted the importance of validating the accuracy of dental age estimation methods across different populations, considering the influence of various factors such as genetic and environmental variables, dietary habits, growth rates, and ethnicity [8].

Each researcher conducted second measurements on 10 X-ray images at one-month intervals to assess intraclass correlation. Additionally, to ensure calibration between the 2 researchers, 10 measurements were reassessed at one-week intervals to evaluate interclass correlation.

Demographic data, including age and gender, were recorded for each child. Initially, the mean and standard deviations of the calcification grades were calculated and statistically compared by gender. Subsequently, six subgroups were formed based on children's age using six-month intervals: 42–47 months, 48–53 months, 54–59 months, 60–65 months, 66–71 months, and 72–77 months. To keep the groups in a limit

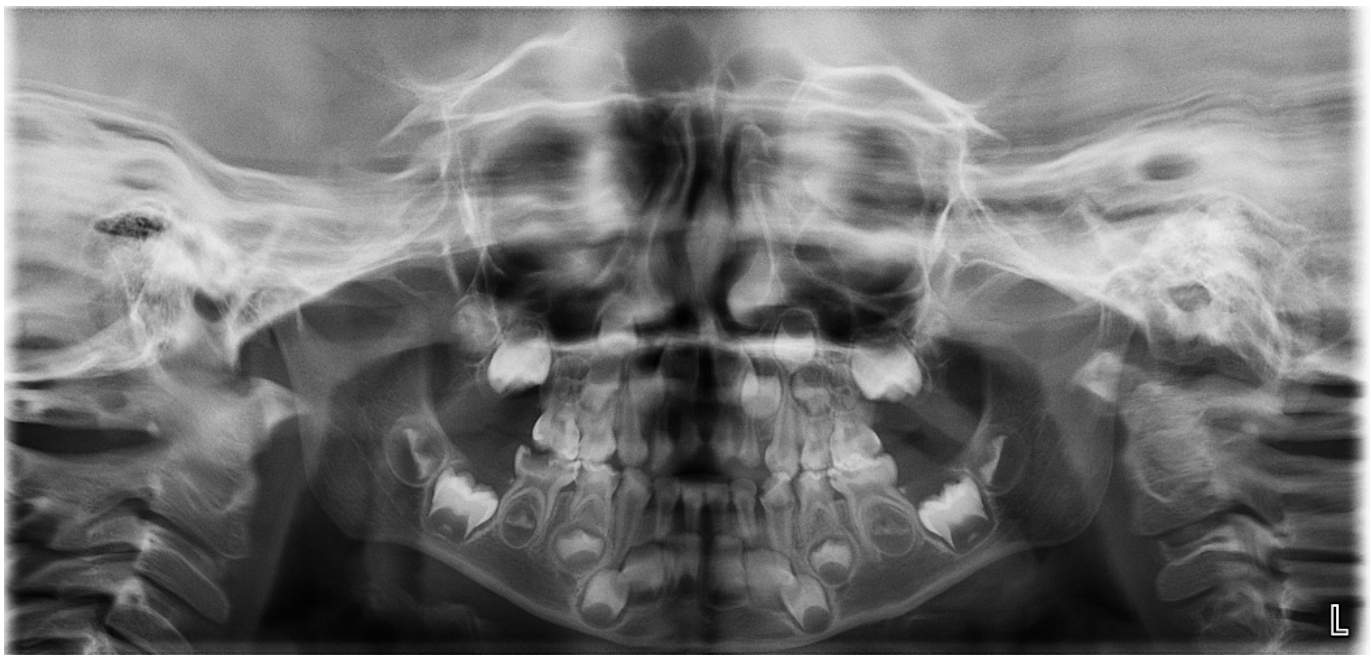

FIGURE 1. Panoramic image of a 4-year old child presenting adequate clear appearances of the posterior teeth germs except maxillary SPs'.

of 6 months intervals, 13 children who aged 78 months old were excluded. Cases where SPs were coded as Grade "0", indicating the absence of dental follicle, were further analyzed statistically by gender and age intervals to indicate potential conditions for second premolar tooth deficiency.

Statistical analysis was conducted using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, NY, USA). A significance level of $p < 0.05$ was applied for all statistical tests. Descriptive statistics, including median (Min–Max) values and arithmetic mean ± standard deviation, are shown. The normal distribution of measurable data was assessed using skewness, kurtosis, and Kolmogorov-Smirnov tests. Mann-Whitney U test was performed for group comparisons, while the chi-square test was used for evaluating categorical data.

3. Results

In this retrospective study, we examined the relationship between calcification grades of SPs and other permanent posterior teeth (including first premolars, and permanent first and second molars) using 9261 panoramic radiographs (PR) to aid clinicians in diagnosing congenitally missing SPs at an early age. Of the 9261 PRs, 481 images (5.2%) were inaccessible in digital storage files. Following exclusion criteria, 223 repetitive images (2.5%), 1691 images with distortions (18.2%), and 53 images showing developmental anomalies, such as shape and number anomalies (0.6%), were eliminated. Ultimately, 6813 images taken from 3663 boys and 3150 girls were included in the study and analyzed by 2 pediatric dentists. Inter-class and intra-class consistency tests yielded scores of 0.94 and 0.93, respectively.

The Nolla grades for all relevant teeth, along with mean and standard deviations, were stratified by gender and presented in Table 1. The mean age of the children was 62.4 ± 9.5 months. Gender-based comparisons revealed higher scores in girls, except for all 4 SPs and tooth numbered 46. In details, all 4 SPs showed higher scores in boys with very similar values of girls' scores. Statistically significant differences were observed for higher scores in girls for 4 first premolars, 3 permanent first molars (Teeth number 46 was statistically higher in boys), and 2 permanent second molars ($p < 0.05$). However, the higher scores were not statistically significant for all 4 SPs and teeth numbered 17, 27 between genders.

Table 2 presents the mean calcification grades of other posterior teeth when an SP tooth had Grade 0. The table emphasizes that when an SP tooth has Grade 0 (*e.g.*, Number (Nu) 15 had Grade 0), the contralateral SP tooth (Nu 25 had 0.37 ± 0.92) has a smaller calcification score than the other SPs located in the opposite jaw (Nu 35; 1.81 ± 1.79 and Nu 45; 1.77 ± 1.73). This fact provides clinicians with valuable information regarding the mean calcification grades of other posterior teeth when the SP has not yet begun to appear.

In Table 3, the distribution of children by gender was statistically analyzed when an SP tooth was classified as Grade 0 on X-ray images. The total numbers of Grade 0 teeth were given in parentheses for each SP in table showing that least number of subjects with a number of 181 was observed for teeth numbered 25. For teeth numbered 15 and 35 and categorized as Grade 0, no statistically significant difference in calcification grades of posterior teeth between boys and girls was observed. However, for teeth numbered 25 and 45 and classified as Grade 0, statistically higher grades for other posterior teeth were found in girls compared to boys.

TABLE 1. The distribution of Nolla grades for each tooth with mean and standard deviations grouped by gender.

Tooth number	Girls	Boys	*p*
14	5.04 ± 1.02	4.90 ± 1.02	0.001*
15	3.87 ± 1.41	3.89 ± 1.32	0.841
16	6.75 ± 0.64	6.67 ± 0.59	0.001*
17	3.72 ± 1.30	3.70 ± 1.20	0.200
24	5.03 ± 1.02	4.90 ± 1.02	0.001*
25	3.90 ± 1.40	3.93 ± 1.28	0.769
26	6.76 ± 0.62	6.66 ± 0.61	0.001*
27	3.72 ± 1.31	3.70 ± 1.20	0.297
34	4.99 ± 1.07	4.79 ± 1.05	0.001*
35	3.85 ± 1.46	3.86 ± 1.37	0.919
36	6.94 ± 0.71	6.83 ± 0.69	0.001*
37	3.83 ± 1.23	3.77 ± 1.12	0.024*
44	5.01 ± 1.06	4.80 ± 1.06	0.001*
45	3.85 ± 1.48	3.85 ± 1.38	0.589
46	6.83 ± 0.69	6.93 ± 0.72	0.001*
47	3.83 ± 1.23	3.78 ± 1.12	0.039*

*Mann Whitney U Tests. * significance was $p < 0.05$.*

Table 4 shows the distribution of children based on subgroups formed with 6-month intervals in cases where SP teeth have Grade 0. Across age intervals, all 4 SPs had the highest number of Grade 0 cases in the youngest group (42–47 months), which may include both congenitally missing teeth and teeth not yet calcified enough to be visible on the panoramic radiographs. This difference was statistically significant (Chi-square, $p < 0.05$). These highest numbers were a combination of congenitally missing or delayed calcification cases seen at early ages of children.

4. Discussion

Diagnosing congenitally missing SPs remains challenging, particularly in early childhood. In this present study, we utilized the calcification grades of permanent posterior teeth to aid in diagnosing the congenital absence of these teeth. It is typically recommended to wait until the end of 3 years of age to confirm the congenital absence of SPs, as their calcification typically starts around 2–2.5 years of age [6, 7]. However, literature reports have documented cases where the onset of mandibular second premolar calcification was observed after the age of five years [6, 7]. To account for potential delays in calcification, we performed an analysis on children aged 42–78 months to minimize the possibility of overlooking delayed calcification.

TABLE 2. The mean and standard deviations for the calcification grades of permanent posterior teeth when a second premolar tooth had Grade 0.

Teeth number	Number 15; Grade 0 (n: 223)	Number 25; Grade 0 (n: 181)	Number 35; Grade 0 (n: 226)	Number 45; Grade 0 (n: 229)
14	3.69 ± 1.21	3.52 ± 1.14	3.94 ± 1.36	3.88 ± 1.32
15	Grade 0	0.37 ± 0.92	1.81 ± 1.79	1.77 ± 1.73
16	6.16 ± 0.83	6.14 ± 0.71	6.27 ± 0.75	6.28 ± 0.71
17	1.78 ± 1.65	1.58 ± 1.54	2.27 ± 1.72	2.30 ± 1.63
24	3.62 ± 1.25	3.48 ± 1.23	3.95 ± 1.37	3.89 ± 1.32
25	0.79 ± 1.32	Grade 0	1.91 ± 1.75	1.81 ± 1.71
26	6.21 ± 0.69	6.16 ± 0.67	6.31 ± 0.63	6.32 ± 0.58
27	1.81 ± 1.63	1.51 ± 1.54	2.27 ± 1.72	2.29 ± 1.63
34	3.74 ± 1.11	3.65 ± 1.01	3.93 ± 1.21	3.87 ± 1.16
35	1.33 ± 1.49	1.11 ± 1.35	Grade 0	0.61 ± 1.20
36	6.38 ± 0.66	6.33 ± 0.65	6.42 ± 0.65	6.46 ± 0.64
37	2.42 ± 1.38	2.02 ± 1.28	2.42 ± 1.48	2.49 ± 1.41
44	3.71 ± 1.22	3.64 ± 1.12	3.91 ± 1.32	3.86 ± 1.27
45	1.35 ± 1.49	1.05 ± 1.34	0.62 ± 1.29	Grade 0
46	6.38 ± 0.67	6.34 ± 0.64	6.41 ± 0.67	6.44 ± 0.65
47	2.27 ± 1.39	2.04 ± 1.26	2.43 ± 1.49	2.50 ± 1.43

TABLE 3. The distribution of children by gender in case of SP teeth have Grade 0.

Teeth numbered 15 (n: 223)		Teeth numbered 25 (n: 181)		Teeth numbered 35 (n: 226)		Teeth numbered 45 (n: 229)	
Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
n: 100 (44.8%)	n: 123 (55.2%)	n: 73 (40.3%)	n: 108 (59.7%)	n: 103 (45.6%)	n: 123 (54.4%)	n: 99 (43.2%)	n: 130 (56.7%)
p: 0.124		*p*: 0.009*		*p*: 0.183		*p*: 0.041*	

*Chi square test, * significance was $p < 0.05$.*

TABLE 4. The distribution of children based on subgroups formed with six-month intervals in case of SP teeth have Grade 0.

Subgroup	Teeth numbered 15 have Grade 0 (n: 223)	Teeth numbered 25 have Grade 0 (n: 181)	Teeth numbered 35 have Grade 0 (n: 226)	Teeth numbered 45 have Grade 0 (n: 229)
42–47 months (n: 669)	n: 94*	n: 84*	n: 65*	n: 67*
48–53 months (n: 918)	n: 37	n: 28	n: 44	n: 43
54–59 months (n: 1213)	n: 25	n: 20	n: 31	n: 35
60–65 months (n: 1320)	n: 22	n: 18	n: 30	n: 32
66–71 months (n: 1531)	n: 25	n: 20	n: 33	n: 30
72–77 months (n: 1149)	n: 20	n: 11	n: 23	n: 22

*Chi square test, * significance was $p < 0.05$.*

Similar results have been documented in previous literature, demonstrating that girls exhibit higher calcification grades and earlier eruption times compared to boys in numerous countries [9–11]. In this study, we observed that the Nolla calcification grades of posterior permanent teeth in girls were generally higher than those in boys. Statistical significance was observed in these differences between boys and girls for all posterior permanent teeth, except for all 4 SPs and teeth numbered 17 and 27, which aligns with previous research highlighting the prevalence of developmental variations, particularly in SPs [6, 7].

Table 2 was designed to provide data to clinicians to assess the relationship between the anticipated calcification grade levels of SPs and other posterior permanent teeth when an SP tooth is graded as 0, enabling them to discuss the mean calcification grades of other posterior teeth when the SP has not yet become visible. Understanding the calcification grades of posterior permanent teeth provides valuable insights into dental maturity and the likely calcification grades of SPs, aiding in the diagnosis of congenitally missing teeth. This evidence-based data assists dentists in making informed decisions regarding the congenital absence of SP teeth, particularly at an early age when other permanent posterior teeth are more clearly visible on radiological images. Panoramic imaging is preferred as the primary modality for detecting dental anomalies due to its ability to provide a comprehensive assessment of the entire dental system, including the maxilla, mandible, alveolar processes, dentition, and nasal cavity. The European Academy of Paediatric Dentistry (EAPD) recognizes panoramic radiographs (PRs) as suitable tools for identifying generalized dental anomalies, such as hypo- or hyperdontia, especially in children who may have difficulties with intraoral imaging positioning and stability [12]. In our study, PRs were chosen as the imaging technique to visualize all 4 quadrants of the jaws in young children, approximately 62.4 $\pm$ 9.5 months of age, who could demonstrate good cooperation to ensure adequate image quality on PRs.

Several methods exist for estimating dental age using dental X-ray images, each with its own advantages and disadvantages. Studies have consistently shown that Nolla's estimation method is more accurate than other methods for the Turkish population [13–16]. Additionally, many methods utilize grade "0" to denote cases where there is no sign of calcification, regardless of the presence of a follicle. In our study, we preferred the Nolla method because its grade "0" allows for the description of the absence of a dental follicle when it cannot be observed. According to the Nolla method, the presence of a follicle is considered a potential indicator of a tooth that will form in the future, and a score of "1" is assigned for this stage. Therefore, cases where the follicle of the second premolar could not be observed and received a score of "0" were examined separately in our study to assess tooth agenesis. Previous studies have indicated that congenitally missing SPs are more common in girls than boys, with the mandibular second premolar being the most frequently missing tooth, followed by the maxillary second premolar [17, 18]. However, conflicting findings exist, with some studies suggesting no gender difference in cases of congenitally missing SPs [19, 20]. In our panoramic radiographs, a total of 455 mandibular second premolar teeth and 404 maxillary second premolar teeth were scored as Grade 0. Table 3 revealed no significant difference between boys and girls when teeth numbered 15 and 35 had Grade 0; however, significant differences between genders were observed for teeth numbered 25 and 45.

Similar differences in calcification degrees of posterior teeth, including delayed eruption times, have been reported in numerous studies. Specifically, it was found that girls generally exhibit earlier eruption times compared to boys, aside from SPs [10]. Various factors, such as genetics, hormonal factors, gender, race, craniofacial morphology, nutrition and growth parameters, can influence delays in tooth eruption [10, 21]. SPs have also been documented to exhibit developmental variations [6, 7]. Despite the minimum age of 42 months in our study group, which surpasses the expected onset time of calcification for SPs, there is a limitation in our study due to the lack of clinical and radiological follow-ups to confirm how many Grade 0 cases resulted in absolute congenital absence in the future.

Further analysis indicated a significant increase in the number of children was observed in the youngest group (42–47 months old) across all six subgroups (Table 4), highlighting the delayed visibility of follicles of SPs at younger ages. Based on these findings, it is suggested to wait until children reach 4 years of age before determining tooth agenesis. In Rune's study, a delay in the calcification grades of contralateral teeth to likely missing teeth was reported [22], which was also evident in our results. In addition, we observed that when a maxillary SP had Grade 0 (Table 2), the contralateral one exhibited a lower calcification score than the mandibular SPs' calcification scores, and *vice versa* when a mandibular SP had Grade 0, the contralateral one had a lower calcification score than the maxillary SPs. Awareness of such delays in the calcification grades of contralateral teeth can guide clinicians to be suspicious of congenitally missing teeth.

5. Conclusions

Observing and interpreting the calcification grades of other permanent posterior teeth can offer valuable insights into the dental maturity of preschool children. This information can significantly aid in the early detection of existing tooth deficiencies, particularly for SPs, which are challenging to diagnose due to their variable calcification grades.

ABBREVIATIONS

SP, second premolar; PR, panoramic radiograph; Nu, number; EAPD, European Academy of Paediatric Dentistry.

AVAILABILITY OF DATA AND MATERIALS

The data are available on request from the corresponding author.

AUTHOR CONTRIBUTIONS

ESK, DB and MB—designed the research study. ESK and DB—performed the analysis. ESK—analyzed the data. ESK and MB—wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethics committee approval (Nu. 2181) was received from Bezmialem Vakif University Non-Interventional Research Ethics Committee. The consent forms were signed by participants and/or their parents.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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