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ORIGINAL RESEARCH

Analysis of the timing and sequence of permanent tooth crown emergence above the alveolar crest in the Korean population

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Abstract

Background: The timing and sequence of permanent tooth eruptions may vary by ethnicity. This study aimed to determine the timing and sequence of permanent tooth crown emergence above the alveolar crest in healthy Korean children and adolescents using recent panoramic radiographs. **Methods**: A total of 8076 panoramic radiographs from Korean children and adolescents aged 4–14 years were initially reviewed, and 1470 radiographs from 1430 healthy patients (775 males and 655 females) were ultimately selected for inclusion. The emergence of permanent teeth in the radiographs was assessed based on the cemento-enamel junction line of the preceding primary tooth or adjacent tooth. Age, sex and Demirjian developmental stage at tooth emergence were evaluated. Comparisons were made between sexes and between teeth with and without previous pulp treatments of primary antecedents. The sequence of tooth emergence was also investigated. **Results**: The mandibular central incisor was the first to erupt at an average age of 6.02 years. Maxillary teeth erupted later than their mandibular counterparts, except for the premolars. Females experienced tooth emergence earlier than males. Pulp treatment of primary molars was associated with accelerated emergence of permanent successors. All teeth, except for the maxillary second molar, showed emergence at Demirjian stage F. The sequence of tooth emergence was slightly different between arches. **Conclusions**: This study presents updated data on permanent tooth emergence in Korean children and adolescents. These findings underscore the need for population-specific eruption references in pediatric dental practice.

Keywords

Tooth emergence; Child; Adolescent; Timing; Sequence; Alveolar crest

1. Introduction

The development of primary teeth begins in the fifth month of embryonic life and proceeds rapidly thereafter [1]. Permanent teeth develop near the apices of primary teeth and initiate pre-eruptive tooth movement at the end of the early bell stage, lasting until the beginning of tooth root formation [2]. During the intraosseous and supraosseous stages of eruptive tooth movement, the epithelial structure known as Hertwig's epithelial root sheath and the dental mesenchyme signal each other to achieve rapid elongation of the tooth root [2]. Thickening and transformation of the reduced enamel epithelium, along with its fusion with the oral mucosa, occur as the erupting tooth approaches the surface epithelium; eventually, the tooth penetrates the gingiva [3]. The functional phase is the period during which the root continues to grow, the length of the clinical crown increases, and the process of active eruption is completed [4].

Among the processes of tooth eruption, tooth emergence into the oral cavity is the easiest to clinically recognize. Tooth emergence is defined as the appearance of any part of a crown in the oral cavity [5, 6]. The first permanent teeth to emerge are the mandibular first molars and central incisors, typically between the ages of 6 and 7 years [1]. In general, the timing of tooth emergence varies among individuals. Although permanent tooth emergence is substantially influenced by genetic factors, it can also be affected by factors such as sex, socioeconomic status [7], neonatal conditions [8], and body composition [9, 10]. Furthermore, localized factors such as dental caries, premature loss of primary teeth [11], and pulp treatment of primary teeth [12, 13] can impact the timing of tooth emergence. Environmental factors, including vitamin D deficiency [14] and X-ray radiation [15], as well as genetic, systemic, and nutritional factors, such as weight and height, can also influence tooth development and emergence [16].

The timing and sequence of tooth emergence can be used to evaluate dental maturity and manage eruption disturbances in pediatric dentistry. The characteristics of distinct ethnic groups and populations and the timing of permanent tooth emergence vary [17]. Furthermore, within the same racial

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and ethnic population, children exhibit differences in growth during different study periods, leading to variations in the timing of permanent tooth emergence [18]. Therefore, assessing tooth crown emergence above the alveolar crest can be considered a scientific method, as panoramic radiographs can be utilized to illustrate the anatomical emergence of tooth crowns. Currently, studies on permanent tooth emergence in Koreans are limited and often outdated, with samples ranging from 1984 to 2003 [5, 19]. Considering improvements in oral health and reported physical growth and development, new standards for permanent tooth emergence need to be established.

Additionally, previous studies have typically performed clinical examinations or used dental casts when examining tooth emergence; however, none have employed radiographic analysis. By utilizing panoramic radiography to determine tooth emergence and using the cemento-enamel junction (CEJ) as the criterion, previous studies can be revisited, allowing for more automated analysis. The use of panoramic radiography in examining tooth emergence can overcome limitations in inter-investigator reliability and reproducibility, which may result from the effort involved in oral examinations and dental casts, and can later facilitate artificial intelligence (AI)-based big data analysis.

This study aimed to investigate the timing and sequence of permanent tooth crown emergence through panoramic radiography in Korean children and adolescents, considering potential differences from other ethnicities and possible secular trends.

2. Materials and methods

This retrospective study was approved by the Institutional Review Board of Seoul National University Dental Hospital, Seoul, Korea (IRB No. ERI24001). The requirement for informed consent was waived.

2.1 Sampling

A total of 8076 panoramic radiographs taken between January and December 2021 from Korean children and adolescents aged 4–14 years at the Seoul National University Dental Hospital were screened. Patients with systemic diseases, maxillofacial deformities, maxillary and mandibular pathologies, ectopic tooth eruptions, tooth agenesis and poor image quality were excluded. Those with primary teeth who had a history of pulp treatment were included unless periapical radiolucencies were present around the primary teeth. Ultimately, 1470 panoramic radiographs from 1430 healthy patients (775 males and 655 females) showing tooth emergence were included in the analysis. Electronic dental record information was also used to reference tooth emergence. A total of 40 patients were sampled twice because their panoramic radiographs showed tooth emergence in different teeth. The average time interval between the radiographs was 5.8 $\pm$ 2.94 months.

2.2 Assessment of tooth emergence

Emergence of all permanent teeth, except for the third molars, was evaluated using the criterion shown in Fig. 1. Incisors were deemed to show emergence if any part of the crown was above the CEJ line of the antecedent or adjacent primary tooth. For canines and premolars, if the antecedent or adjacent primary tooth was present, the tooth was considered to have erupted if any part of the crown was above the CEJ line of the antecedent or adjacent primary tooth. In the absence of both antecedent and adjacent primary teeth, the line was positioned according to the CEJ line of the second adjacent primary tooth or the fully erupted first molar. For molars, emergence was determined if any part of the crown was above the CEJ line of the adjacent primary tooth or the fully erupted first molar. Electronic dental record information was also used to reference tooth emergence.

2.3 Assessment of age and dental developmental stage at the time of tooth emergence

Patients' sex and age at tooth emergence were recorded, and the sequence of tooth emergence was examined by calculating the mean age at tooth emergence for each tooth. Additionally, several pairs of teeth (central incisor–first molar, canine–first premolar, second premolar–second molar in both the maxillary and mandibular arches, and maxillary central incisor–mandibular lateral incisor) thought to erupt within a similar age range were compared. The tooth that erupted earlier in each pair was recorded for each panoramic radiograph and expressed as a percentage.

A history of pulp treatment, such as pulpotomy and pulpectomy, of primary molars was also documented. The dental developmental stages of all permanent teeth, except for the third molars at the time of tooth emergence, were analyzed on panoramic radiographs using the dental maturity rating system suggested by Demirjian *et al*. [20]. Stages E, F, G and H were particularly relevant to tooth emergence, with the following criteria:

- Stage E: The crown of the tooth is fully formed, and the root begins to elongate. During this stage, the bifurcation of molar roots becomes visible, and approximately one-third of the final root length is achieved.
- Stage F: The root length reaches or exceeds the height of the crown. Although the root canal walls are still divergent at this stage and the apical end remains open with a funnel-like shape, this is typically when tooth eruption into the oral cavity occurs.
- Stage G: The root canal walls become parallel, but the apical end remains partially open, indicating that although the root is nearly complete, it is not fully closed.
- Stage H: The root is fully formed, and the apex is completely closed, marking the tooth as fully mature [20].

All evaluations were conducted by one pediatric dentist (S. Kim). Intraobserver agreement was confirmed by re-evaluating 100 randomly selected panoramic radiographs at 2-week intervals. The left and right corresponding teeth in the same arch were treated as a whole without distinction.

2.4 Statistical analysis

The mean ages at emergence for each tooth were calculated. The independent t-test was employed to compare the mean

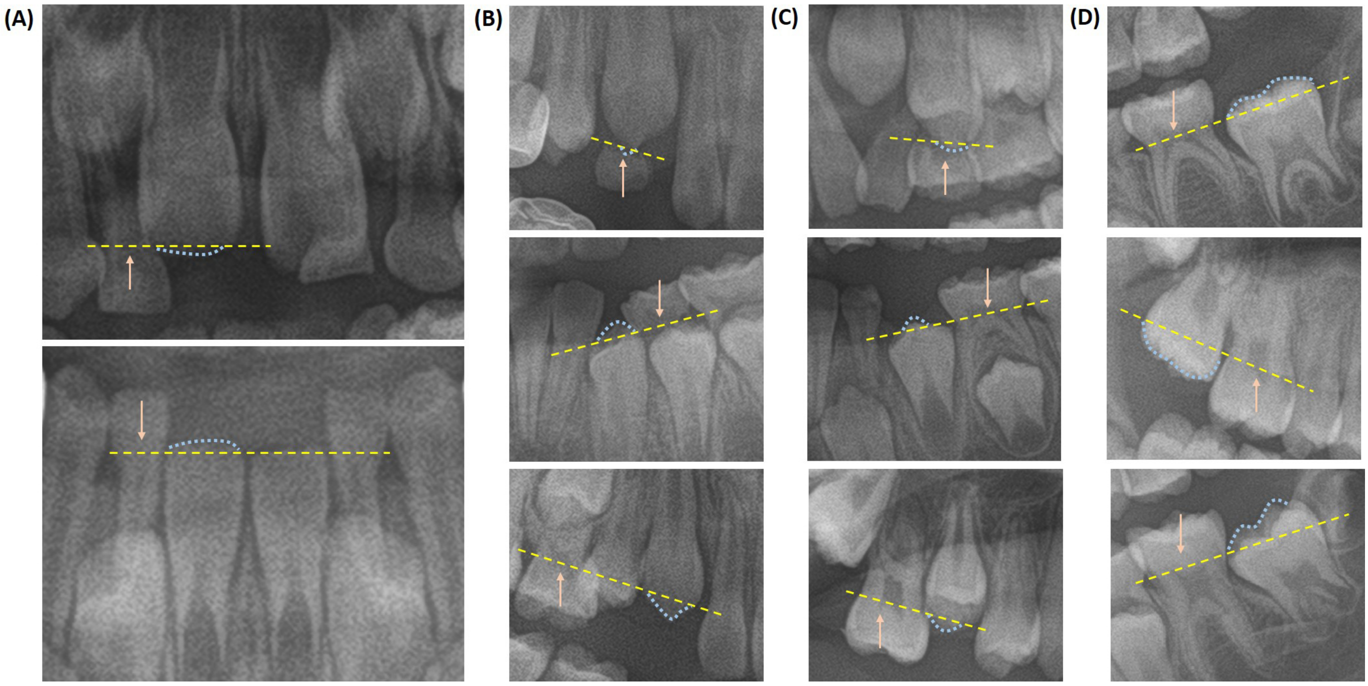

FIGURE 1. Criteria for tooth emergence from panoramic radiography in (A) incisors, (B) canines, (C) premolars and (D) molars. The yellow dashed line represents the criterion line for tooth emergence, the orange arrow indicates the tooth used as the reference for the CEJ line, and the light blue dotted line outlines the border of the tooth that has erupted above the criterion line.

ages between males and females and between the maxillary and mandibular arches. Comparisons of ages at emergence of the permanent teeth in primary molars with and without a history of pulp treatment were performed using the independent samples *t*-test. The Demirjian stage of each permanent tooth was analyzed through frequency analysis, and the median was also recorded. The percentage of each stage for each tooth was calculated. Intraobserver agreement was evaluated using Cohen's unweighted kappa for tooth emergence and weighted kappa for dental developmental stages.

3. Results

3.1 Intraobserver agreement

Cohen's unweighted kappa value for intraobserver agreement regarding tooth emergence was 0.98 ($p < 0.001$). Meanwhile, Cohen's weighted kappa value for intraobserver agreement regarding dental developmental stages was 0.93 ($p < 0.001$).

3.2 Age distribution at the time of tooth emergence and comparison between males and females

The mean ages at the time of tooth emergence for each tooth and the comparison between males and females are shown in Table 1. Among the teeth, the mandibular central incisor (LI1) penetrated the gingiva first at a mean age of 6.02 ± 0.59 years. The mandibular first molar (LM1) and maxillary first molar (UM1) emerged at mean ages of 6.40 ± 1.35 and 6.73 ± 1.06 years, respectively. The maxillary central incisor (UI1) penetrated the gingiva at a mean age of 7.05 ± 0.75 years, whereas the mandibular lateral incisor (LI2) emerged at a mean age of 6.86 ± 0.78 years. LI2 emerged at an earlier age than UI1.

Females experienced tooth emergence earlier than males for all teeth, with significant differences observed in the maxillary lateral incisor (UI2, $p = 0.008$), maxillary first premolar (UP1, $p = 0.010$), mandibular central incisor (LI1, $p = 0.037$), mandibular canine (LC, $p < 0.001$), and mandibular first premolar (LP1, $p = 0.046$).

3.3 Tooth emergence in maxillary and mandibular arches

Comparisons between the maxillary and mandibular arches are also shown in Table 1 (rightmost column). The mandibular teeth erupted earlier than the corresponding maxillary teeth, except for the first and second premolars, where the difference was not significant.

3.4 Sequence of tooth emergence

The sequence of emergence of the permanent teeth according to the mean age at tooth emergence is shown in Fig. 2. The sequence was UM1–UI1–UI2–UP1–maxillary canine (UC)–maxillary second premolar (UP2)–maxillary second molar (UM2) in the maxilla, and LI1–LM1–LI2–LC–LP1–mandibular second premolar (LP2)–mandibular second molar (LM2) in the mandible. Fig. 3 presents a comparison of pairs of teeth thought to erupt at a similar time. To determine which tooth first emerges into the oral cavity, LI1 and LM1 were compared, and no significant difference was observed (50.9% *vs*. 49.1%). Unlike the mandibular arch, UM1 erupted earlier

TABLE 1. Age distribution at the time of tooth emergence and comparison between males and females and between maxillary and mandibular teeth in 1430 Korean children.

	Ages (yr)						$p^{\dagger}$	Ages (yr)			$p^{\ddagger}$
	Male			Female				Total			
	Mean	SD	N	Mean	SD	N		Mean	SD	N	
Central incisors											
Maxillary	7.22	0.78	28	6.85	0.68	26	0.075	7.05	0.75	54	<0.001*
Mandibular	6.11	0.64	84	5.90	0.50	60	0.037*	6.02	0.59	144	
Lateral incisors											
Maxillary	8.22	0.84	63	7.83	0.77	55	0.008*	8.04	0.83	118	<0.001*
Mandibular	6.88	0.69	88	6.84	0.89	67	0.768	6.86	0.78	155	
Canines											
Maxillary	10.27	1.10	77	9.93	1.05	70	0.056	10.11	1.08	147	<0.001*
Mandibular	9.91	0.95	84	9.22	1.04	95	<0.001*	9.54	1.05	179	
1st premolars											
Maxillary	9.93	1.10	140	9.59	0.98	119	0.010*	9.77	1.06	259	0.488
Mandibular	9.96	1.13	108	9.73	0.97	112	0.046*	9.84	1.06	220	
2nd premolars											
Maxillary	10.65	1.31	67	10.58	1.25	65	0.773	10.61	1.28	132	0.968
Mandibular	10.75	1.18	58	10.48	1.01	63	0.192	10.61	1.10	121	
1st molars											
Maxillary	6.78	1.09	56	6.65	1.01	30	0.577	6.73	1.06	86	0.046*
Mandibular	6.45	1.29	107	6.30	1.48	52	0.511	6.40	1.35	159	
2nd molars											
Maxillary	12.52	0.89	17	12.23	1.12	18	0.410	12.37	1.01	35	<0.001*
Mandibular	10.79	1.89	23	10.52	1.69	22	0.627	10.66	1.78	45	

†*Comparison between males and females (independent t-test).*
‡*Comparison between maxillary and mandibular teeth (independent t-test).*
**Significant ($p < 0.05$).*
SD: standard deviation.

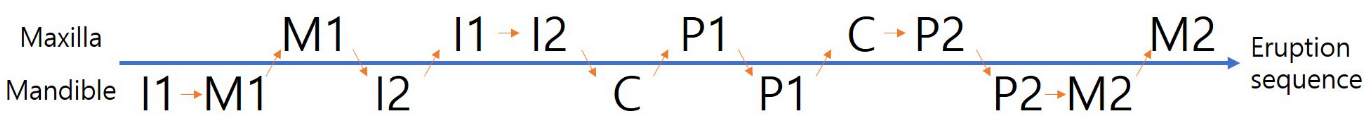

FIGURE 2. Eruption sequence of permanent teeth according to the mean age at tooth emergence. I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar. The upper row represents the maxillary teeth, whereas the lower row represents the mandibular teeth. If a tooth number is written on the left side of the arrow, it indicates that it erupts earlier than the tooth number written on the right side.

than UI1 in 71.8% of cases, whereas the opposite occurred in 28.2%. Furthermore, UP1 erupted earlier than UC in 88.3% of cases, with the opposite occurring in 11.7%. Conversely, LC erupted earlier than LP1 in 67.3% of cases, whereas the opposite occurred in 32.7%. This indicates that the maxillary and mandibular teeth exhibit different tendencies in tooth emergence. In both the maxilla and mandible, UP2 and LP2 tended to erupt earlier than UM2 and LM2, respectively, with the maxilla showing a more pronounced tendency for earlier second premolar eruption. LI2 erupted earlier than UI1 in 67.6% of cases, whereas the opposite occurred in 32.4%.

3.5 Comparison of ages at the time of tooth emergence with and without pulp treatment history of primary antecedents

Table 2 presents a comparison of the ages of tooth emergence for permanent successors with and without pulp treatment of primary molars. Pulp treatment of primary antecedents accelerated the emergence of permanent teeth. Significant differences were observed in UP2 (p = 0.010) and LP1 (p = 0.046).

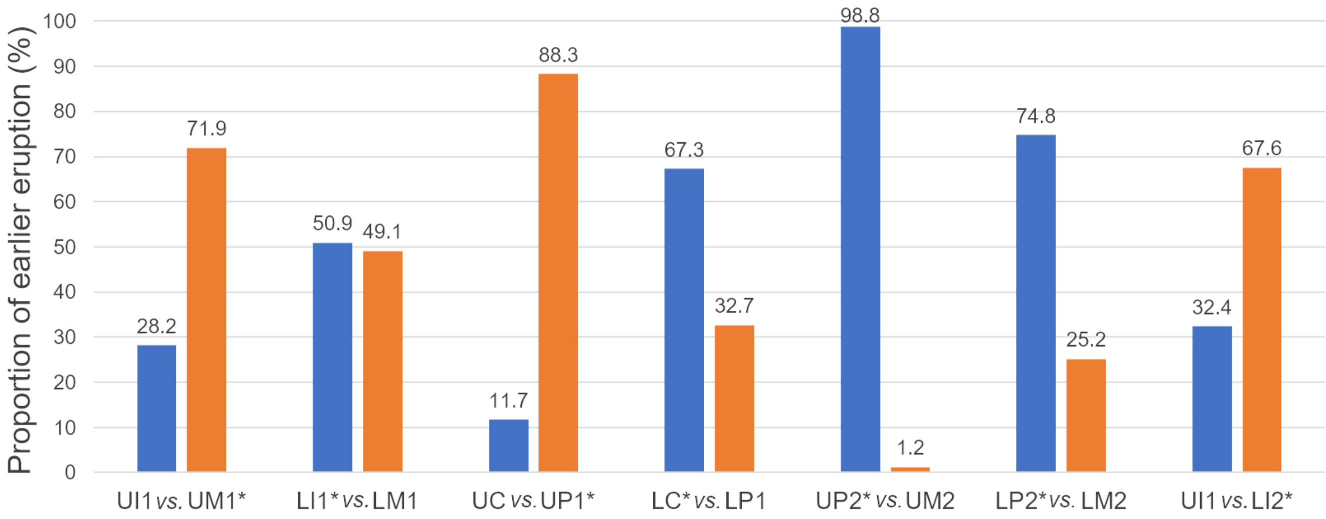

FIGURE 3. Comparisons between tooth pairs that typically show emergence at the same age. The x-axis represents the tooth pairs that emerge around the same time on panoramic radiography, whereas the y-axis displays the percentage of panoramic images in which one tooth of the pair erupts earlier than the other. The unit is expressed as a percentage (%). * indicates the tooth that usually emerges earlier within the pair. UI1, maxillary central incisor; UC, maxillary canine; UP1, maxillary first premolar; UP2, maxillary second premolar; UM1, maxillary first molar; UM2, maxillary second molar; LI1, mandibular central incisor; LI2, mandibular lateral incisor; LC, mandibular canine; LP1, mandibular first premolar; LP2, mandibular second premolar; LM1, mandibular first molar; LM2 mandibular second molar.

TABLE 2. Comparison of ages (years) at the time of tooth emergence with and without pulp treatment history of primary antecedents.

	Without pulp treatment history			With pulp treatment history			$p^{\dagger}$
	Mean	SD	N	Mean	SD	N	
Maxillary							
First premolar	9.92	0.94	114	9.53	1.22	32	0.056
Second premolar	10.84	1.11	70	9.91	1.45	13	0.010*
Mandibular							
First premolar	9.94	1.25	70	9.35	1.20	22	0.046*
Second premolar	10.76	1.02	51	10.20	0.96	14	0.071

† Independent t-test was used for comparison.
**Significant ($p < 0.05$).*
SD: standard deviation.

3.6 Demirjian developmental stages at the time of tooth emergence

Fig. 4 shows the dental developmental stages of each tooth. Nearly all teeth exhibited emergence at Demirjian stage F, except for UM2, which erupted at stage G. Notably, 100% of UI1 emerged at Demirjian stage F. Among all emerging UI2, 94.9% were at Demirjian stage F, which was the second-highest percentage among all teeth. Similar results were observed for other teeth: UC, UP1, UP2, UM1 and UM2 emerged at Demirjian stage F in 75.5%, 86.5%, 70.6%, 89.5% and 42.9% of cases, respectively, whereas LI1, LI2, LC, LP1, LP2, LM1 and LM2 emerged at the same stage in 88.2%, 82.6%, 87.2%, 79.1%, 76.8%, 70.4% and 66.7% of cases, respectively.

4. Discussion

An early study on tooth emergence was conducted by Kronfeld [1] using the skulls of Caucasians, where they established the criteria for tooth emergence. In the present study, UC, UP1, LI2, LP1, LP2 and LM2 exhibited tooth emergence at an earlier age than those reported in Kronfeld's study [1]. The present results revealed earlier tooth emergence compared to those of Indian [21] and Finnish [22] populations. Among these, the Indian [21] population showed a greater difference, with an average age of 0.7 years earlier than in the present study. In Greece [23], Denmark [24], Spain [25] and the UK [26], the timing of tooth emergence for incisors and molars was similar; however, canines and premolars emerged earlier than in the population studied here. Notably, the Ugandan [27] population exhibited earlier tooth emergence than the population in the present study. These results may suggest racial differences.

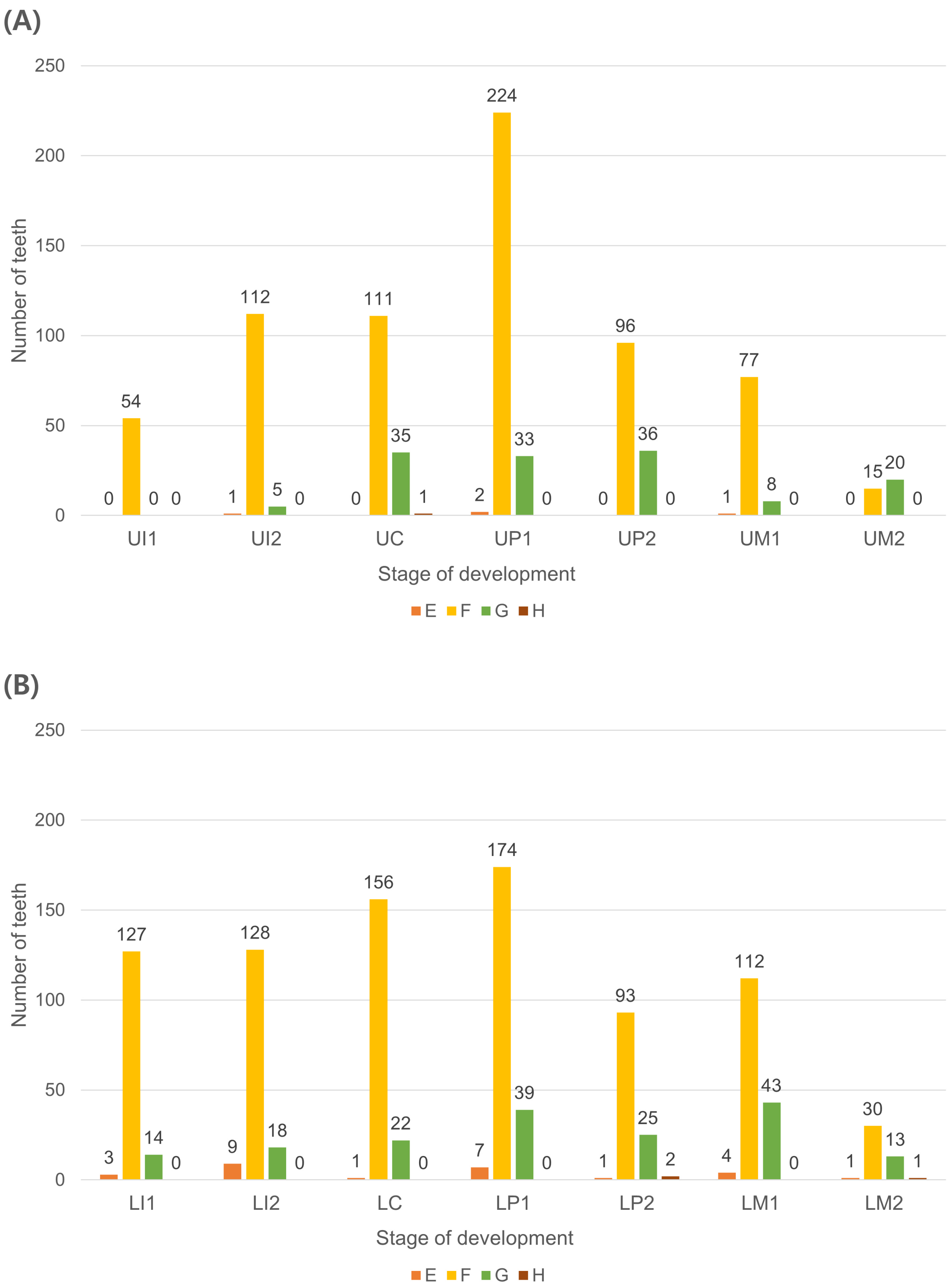

FIGURE 4. Distribution of Demirjian developmental stages of the (A) maxillary teeth and (B) mandibular teeth at the time of tooth emergence. The x-axis represents the Demirjian developmental stages of each tooth, whereas the y-axis indicates the number of teeth corresponding to each developmental stage. UI1, maxillary central incisor; UI2, maxillary lateral incisor; UC, maxillary canine; UP1, maxillary first premolar; UP2, maxillary second premolar; UM1, maxillary first molar; UM2, maxillary second molar; LI1, mandibular central incisor; LI2, mandibular lateral incisor; LC, mandibular canine; LP1, mandibular first premolar; LP2, mandibular second premolar; LM1, mandibular first molar; LM2, mandibular second molar.

Other studies also indicate that the timing of tooth emergence varies among races and ethnic groups. A study investigated global variations in the chronology of permanent tooth emergence, revealing that the ages of permanent teeth eruption were advanced in the European population, followed by those in Africa and Asia [17].

A secular trend can be observed when comparing the present study with previous ones involving Korean children. Compared to studies conducted by Moon *et al.* [19] and Kim *et al.* [5], LM2 in the present study showed the most significant difference, with earlier tooth emergence observed. This overall acceleration in tooth emergence, particularly for LM2, can likely be attributed to improvements in physical growth and development in children over recent decades [28]. Additionally, although we observed earlier emergence for most teeth, there was a tendency for delayed emergence in premolars, which may be linked to the decreasing trend in dental caries in primary molars. In recent years, South Korea has seen an evident decline in the prevalence of dental caries, particularly in children, due to improvements in oral health education, preventive programs, and access to fluoride treatments [29]. This trend has been reported by Kim *et al.* [5], who found that higher dt (decayed teeth) and ft (filled teeth) scores were associated with earlier emergence.

Furthermore, the sequence of tooth emergence differs over time in the Korean population. In studies conducted by Moon *et al.* [19] and Kim *et al.* [5], LM1 was the first tooth to penetrate the gingiva; however, in the present study, it was LI1, although the difference was not significant (Table 1). In the present study, UP1 emerged earlier than UC, and LC emerged earlier than LP1, whereas in the study conducted by Kim *et al.* [5], LP1 emerged earlier than LC in females.

The results of this study may differ from those of previous Korean studies because this study used panoramic radiographs to evaluate tooth emergence, whereas Moon *et al.* [19] and Kim *et al.* [5] used oral examinations and dental casts, respectively. Unlike oral examinations or dental models, panoramic radiographs are thought to have the following three advantages. First, the criteria established according to the CEJ line of preexisting teeth can provide more accurate assessments, as they can identify false-negative results when a preexisting primary tooth does not exfoliate even though the permanent successors have penetrated the gingiva beneath the primary tooth. Second, a panoramic radiograph can screen for dental problems such as maxillary or mandibular pathologies, ectopic eruption or tooth agenesis, which can affect the timing and sequence of tooth emergence [30]. Finally, unlike oral examination or dental cast evaluation, panoramic radiography does not require multiple investigators, which can lead to issues with agreement among them, and it can be used in AI analysis in further studies [30].

This study confirmed that UI2, UP1, LI1, LC and LP1 emerged earlier in females than in males. For other teeth, although the differences were not significant, females tended to experience earlier tooth emergence. Slovenian females generally showed earlier tooth emergence than males, except for the maxillary and mandibular second premolars and second molars, which emerged earlier in males [6]. These differences could be attributed to the earlier maturation of females, whereas the later onset of puberty in males may lead to catch-up development by the age of eruption of the second molars. However, the present study showed no significant difference in late-erupting teeth such as second premolars and molars, suggesting that these are less affected by sex differences, as they are positioned posteriorly. Further investigation is warranted to confirm these propositions. Additionally, mandibular teeth emerged earlier than maxillary teeth, although the results for premolars were not significant, consistent with the findings of previous studies [5, 23].

The sequence of tooth emergence in the present study can also be compared with those in other studies conducted in different countries. LI1 tended to emerge earlier than LM1 in the present study. Some studies in other countries have also questioned the conventional idea that LM1 is the first tooth to erupt in the oral cavity. In the Finnish [22], Danish [24] and Irish [26] populations, LI1 tended to erupt earlier than LM1. Conversely, in the Ugandan [27], Indian [21] and Slovenian [6] populations, LM1 emerged earlier than LI1. When comparing UC with UP1 and UP2 with UM2, the Irish [26], Ugandan [27], Indian [21], Finnish [22] and Danish [24] populations, along with the present study, showed earlier emergence of UC and UP2 than of UP1 and UM2, respectively, with no exceptions. However, when comparing LC with LP1, the Indian [21] and Ugandan [27] populations showed earlier emergence of LC than LP1, contrary to the results from the present study. Meanwhile, the Irish [26], Slovenian [6], Finnish [22] and Danish [24] populations, as well as the present study, showed earlier emergence of LP1. LP2 emerged earlier than LM2 in the Irish [26], Ugandan [27], Indian [21] and Finnish [22] populations and in the present study, whereas LP2 and LM2 emerged at similar times in the Danish [24] population.

The results of this study indicated that pulp treatment in primary molars accelerated the eruption of permanent teeth. A significant tendency was noted for the succedaneous premolar beneath the pulpotomized primary molar treated with formocresol to erupt at an accelerated rate [12]. Pulpectomy was found to accelerate the root resorption of primary teeth in several studies. The use of calcium hydroxide-containing root-filling pastes in vital pulp tissue can also promote primary root resorption, leading to the early eruption of permanent teeth [13]. Furthermore, another study [31] reported that calcium hydroxide induced a chronic inflammatory response that influenced macrophages to fuse and form odontoclasts. Although no study has investigated the correlation between the timing of emergence and pulpectomy of the primary molar, primary root resorption can facilitate the eruption of permanent teeth.

All teeth emerged at Demirjian stage F in more than half of the cases, except for UM2, which was at stage G. Demirjian stage F is characterized by a root length that is equal to or greater than the crown height, with the apex ending in a funnel shape [20]. Conversely, Demirjian stage G occurs when the walls of the root canal are parallel and the end remains partially open [20]. UM2 and LM2 emerged relatively later than the other teeth when comparing their Demirjian stages, which can be interpreted as reflecting the secular trend of reduced jaw width, along with changes in tooth morphology that influence the space and timing of second molar eruption [32].

This study has some limitations. First, panoramic radiography was the only method employed to evaluate tooth emergence. Although electronic dental record information was also used to reference tooth emergence, studies that utilize both panoramic radiographs and clinical observations are warranted. Thus, there may have been a time difference between the actual timing of eruption and the timing of the radiographs. Second, the analysis of reliability and interpretation was lacking between patients' clinical photos and the radiographs. Third, because this study involved patients who visited only one hospital over the course of 1 year, it does not represent the entire Korean population. In the future, a national-level study with a larger sample size may be needed. Additionally, AI-based big data analysis could be conducted based on the methods used in this study.

5. Conclusions

Within the limitations of this study, the findings suggest that permanent tooth emergence in the Korean population generally occurs at Demirjian stage F, with LI1 being the first to emerge at an average age of 6.02 years. For teeth with corresponding names, the mandibular teeth typically emerge through the alveolar bone earlier than the maxillary teeth, and females tend to show earlier tooth emergence compared to males. Additionally, pulp treatment of primary teeth appeared to accelerate the eruption of permanent successors. These findings may provide a reference for understanding the timing and sequence of permanent tooth emergence in Korean children and adolescents, which could assist dental practitioners in managing eruption disturbances or assessing dental maturity.

ABBREVIATIONS

AI, artificial intelligence; CEJ, cemento-enamel junction.

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

HKH and JSS—designed the research study. SJK—performed the research. SJK and JSS—analyzed the data. SJK, HKH and JSS—wrote and revised the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All procedures performed were in accordance with the Ethics Committee of the Seoul National University Dental Hospital, Seoul, Korea (Ethics Code: ER124001). 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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FUNDING

This research received no external funding.

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 affirm that Hong-Keun Hyun had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process of this article was delegated to LAAA.

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