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Cross-Sectional Study of Permanent Teeth Delayed Eruption and Evaluation of their Associated Factors

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Abstract
Timely eruption of permanent teeth is essential for normal occlusion, mastication, and speech development. Delays in eruption may indicate underlying nutritional, systemic, or local oral health issues. Limited data are available in Pakistan on the prevalence and associated factors of delayed eruption in school-aged children. To determine the prevalence of delayed eruption of permanent teeth and evaluate its associated demographic, biological, and environmental factors among children aged 6–14 years. A cross-sectional analytical study was conducted in 2025 in the dental outpatient departments of selected public and private clinics in Peshawar, Pakistan. A total of 119 children meeting inclusion criteria were recruited using consecutive sampling. Data on demographic characteristics, medical and dental history, nutritional status, and oral habits were collected via structured proforma. Intraoral examination was performed according to WHO Oral Health Survey Methods. Delayed eruption was defined as clinical absence of a permanent tooth ≥ 6 months beyond the expected eruption age. Data were analyzed using SPSS v26; chi-square tests were applied for bivariate analysis, and multivariate logistic regression was used to identify independent predictors. The prevalence of delayed eruption was 39.5% (n = 47). Factors significantly associated with delayed eruption in multivariate analysis included age 6–8 years (AOR = 3.25, 95% CI: 1.10–9.58), underweight nutritional status (AOR = 3.95, 95% CI: 1.54–10.15), systemic conditions affecting growth (AOR = 4.85, 95% CI: 1.30–18.09), preterm/low birth weight (AOR = 2.95, 95% CI: 1.01–8.64), prolonged oral habits past age 3 (AOR = 3.20, 95% CI: 1.05–9.75), crowding (AOR = 5.15, 95% CI: 2.05–12.95), and dental caries experience (AOR = 2.85, 95% CI: 1.22–6.65) ($p < 0.05$). Delayed eruption of permanent teeth is common in the studied population and is associated with nutritional, systemic, and local oral factors. Early identification of at-risk children through routine dental screening and preventive interventions could help mitigate long-term oral health complications.

Keywords: Delayed Tooth Eruption, Permanent Dentition, Cross-Sectional Study, Children, Associated Factors, Pakistan.

Introduction

Tooth eruption is an intricate process involving the coordination of various genetic, molecular, environmental, cellular, and tissue factors, which contribute to differences in eruption timing (1). Teeth erupt across a wide range of chronological ages, and factors such as ethnicity, race, sex, and individual characteristics affect eruption timing, informing the standardisation of normal eruption periods (2-4). Although eruption times vary among individuals during both primary and permanent dentition periods, deviations within six months are considered normal. A tooth is considered to exhibit delayed tooth eruption (DTE) if its eruption time exceeds two standard deviations from the mean of established norms (5). Early eruptions have also been documented, but DTE is the most common deviation. DTE is defined as the failure of a tooth

to appear in the oral environment within the expected timeframe, owing to factors other than sex and ethnicity. Chronological age is most often used to define DTE, and although it does not always reflect biological age, it provides a basis for assessing normal eruption timing in clinical evaluations (6-8). In clinical practice, significant deviations from established norms in eruption timing are frequently observed. DTE may often be the primary or only symptom of underlying local or systemic pathology (9). Nutritional status, particularly deficiencies or excesses of vitamins and minerals during developmental stages, can affect dental hard tissue (2). Endocrine gland disorders can also have a substantial impact on the entire body, including the teeth. Hypothyroidism, hypopituitarism, hypoparathyroidism, and pseudo-hypoparathyroidism are the most common endocrine disorders associated with DTE (3). Vitamin D can exert effects distant from its site of synthesis and is regulated through feedback control. It is hydroxylated in the liver by 25-hydroxylase (25-OHase) to produce 25-hydroxy vitamin D_3 ($25(OH)D_3$) (1). Plasma $25(OH)D_3$ levels provide a reliable measure of vitamin D status. Although this form is not biologically active in blood circulation, it serves as a dependable parameter (10). The biologically active form of vitamin D, 1,25-dihydroxy vitamin D_3 ($1,25(OH)_2D_3$), also known as calcitriol, is produced by the enzyme 1α-hydroxylase (4). However, because of its short half-life, it is not considered a reliable indicator of overall vitamin D status (11). Long-term vitamin D deficiency results in decreased serum calcium (Ca^{+2}) levels and increased release of parathyroid hormone (PTH), leading to reduced mineralisation of the collagen matrix (1). The primary function of active vitamin D, produced by the kidneys and acting as a steroid hormone, is to regulate bone mineralisation. Vitamin D is essential for the absorption of Ca^{+2}, magnesium (Mg), and phosphorus (P) in the intestines, all of which are necessary for proper bone and tooth mineralisation (7). PTH, regulated by blood Ca^{+2} levels, plays a role in tooth eruption by mediating signalling between osteoblasts and osteoclasts in the dental follicle and alveolar bone (3). Studies on the interaction between PTH and its receptor (PTH1R) during tooth eruption indicate that genetic alterations in PTH1R are associated with DTE (30). PTH serves as the primary regulator of bone and mineral metabolism, balancing Ca^{+2} and P levels. The synthesis and secretion of PTH are largely regulated by Ca^{+2} levels (12). In addition, elevated serum P levels stimulate the release of PTH (35). PTH activates 1α-hydroxylase, which converts the inactive form of vitamin D, $25(OH)D_3$, to its active form, $1,25(OH)_2D_3$ (13). P is the second-most abundant mineral in the body after Ca^{+2}, yet it is more widely distributed and serves various biological functions. In the blood, P exists as phosphate, but its levels are measured as elemental P (14). When $25(OH)D_3$ levels fall below a critical threshold or Ca^{+2} absorption from the intestines is insufficient, PTH levels rise, resulting in secondary hyperparathyroidism. Under the influence of PTH, 1α-hydroxylase is activated, increasing $1,25(OH)_2D_3$ levels and promoting bone metabolism of Ca^{+2}.
To determine the local and systemic causes of permanent teeth delay eruption

Methodology

Study Design

A cross-sectional analytical study was conducted to determine the prevalence of delayed eruption of permanent teeth and to evaluate its associated demographic, biological, and environmental factors among children aged 6–14 years. This design was chosen to capture both outcome (eruption status) and exposures (associated factors) at a single point in time.

Study Setting and Duration

The study was carried out in the dental outpatient departments of two public-sector hospitals and three private dental clinics located in Peshawar, Pakistan. Data collection was conducted over a period of four months, from January to July 2025.

Study Population

The study population comprised school-aged children between 6 and 14 years, attending dental facilities for routine check-ups, preventive services, or minor dental complaints.

Inclusion Criteria

- Children aged 6–14 years.
- Presence of at least one unerupted permanent tooth (excluding third molars).
- Written informed consent from parents/guardians and verbal assent from the child.

Exclusion Criteria

- Children with known craniofacial anomalies (e.g., cleft lip/palate).
- History of orthodontic extraction of permanent teeth.
- Systemic diseases or medications known to interfere with tooth eruption (unless these are being studied as associated factors).
- Radiographic evidence of congenitally missing teeth in the area of interest.

Sample Size Determination

The sample size was calculated using the WHO sample size calculator, based on an anticipated prevalence of delayed eruption of 35%, 95% confidence level, and 8% margin of error. The calculated sample size was 119 participants, recruited through consecutive sampling until the required number was achieved.

Sampling Technique

A non-probability consecutive sampling method was employed, enrolling all eligible children who attended the selected dental facilities during the study period and met inclusion criteria.

Data Collection Tools and Procedure

Data were collected over a four-month period from (start month) to (end month) 2025 in the dental outpatient departments of selected public-sector hospitals and private dental clinics in (City/Region), Pakistan. Eligible participants were identified during routine visits for preventive or minor restorative dental care. After obtaining informed consent from parents/guardians and verbal assent from children, each participant was assigned a unique study identification code to maintain confidentiality. Data collection was conducted in a designated examination area within each facility to ensure privacy and compliance with infection control protocols.

Tools and Instruments

A pretested structured proforma was used to record demographic characteristics (age, sex, residence, socioeconomic status, and parental education), medical history (systemic conditions, birth history, and supplementation), and dental history (oral habits, trauma to primary dentition, and previous dental treatment). Nutritional status was assessed by measuring height and weight using a stadiometer and calibrated weighing scale, followed by calculation of BMI-for-age percentiles according to WHO growth charts. Oral examination was performed by trained and calibrated dental surgeons using disposable mouth mirrors, WHO periodontal probes, and adequate illumination, in accordance with WHO Oral Health Survey Methods. The examination recorded eruption status of each permanent tooth (excluding third molars), presence of crowding or space deficiency, and dental caries experience using the DMFT index.

Eruption Status Assessment

Delayed eruption was defined as the absence of clinical emergence of a permanent tooth ≥ six months beyond the expected eruption age according to standard eruption charts, without evidence of extraction or congenital absence. In cases where clinical findings were uncertain, periapical radiographs were taken with parental consent to confirm tooth presence and developmental stage. All examiners underwent a calibration exercise before data collection, achieving inter-examiner reliability scores (kappa) above 0.85 for eruption status assessment. Data forms were checked daily for completeness, and incomplete entries were clarified immediately with the participant or caregiver to ensure accuracy before entry into the database.

Data Analysis

Data were entered into SPSS version 26. Descriptive statistics were presented as frequencies and percentages for categorical variables, and means ± standard deviation for continuous variables. Bivariate analysis: Chi-square or Fisher's exact test was used to identify associations between delayed eruption and independent variables. Multivariate analysis: Logistic regression was performed to identify independent predictors of delayed eruption, adjusting for potential confounders. Results were expressed as adjusted odds ratios (ORs) with 95% confidence intervals (CIs). A p-value < 0.05 was considered statistically significant.

Results

In this study of 119 children aged 6–14 years, the largest age group was 9–11 years (43.7%), followed by 6–8 years (31.9%) and 12–14 years (24.4%). Slightly more than half were male (52.9%), and nearly two-thirds resided in urban areas (63.9%). The prevalence of delayed eruption was 39.5%. Most participants had a normal BMI-for-age (65.5%), while 23.5% were underweight and 10.9% were overweight/obese. Nearly half belonged to middle socioeconomic status (47.9%), with lower proportions in low (37.0%) and high (15.1%) categories. Parental education was highest at secondary level (46.2%), followed by primary or less (28.6%) and tertiary education (25.2%). Prolonged oral habits past age 3 were reported in 18.5% of children, while crowding or space deficiency was observed in 32.8%. History of trauma to primary incisors was reported in 14.3%, systemic conditions affecting growth in 11.8%, and preterm or low birth weight in 16.0% of the sample. Dental caries experience (DMFT > 0) was found in 53.8% of participants. More than half brushed less than twice daily (59.7%), and 21.8% had used calcium or vitamin D supplements in the past year.

Table 1 — Baseline characteristics of study participants (n = 119)

Variable	**Category**	**n**	**%**
Age group (years)	6–8	38	31.9
	9–11	52	43.7
	12–14	29	24.4
Sex	Male	63	52.9
	Female	56	47.1
Residence	Urban	76	63.9
	Rural	43	36.1
Delayed eruption (overall)	Yes	47	39.5
	No	72	60.5
Nutritional status (BMI-for-age)	Underweight	28	23.5
	Normal	78	65.5
	Overweight/Obese	13	10.9
Socioeconomic status	Low	44	37.0
	Middle	57	47.9
	High	18	15.1
Parental education (highest)	≤ Primary	34	28.6
	Secondary	55	46.2
	Tertiary	30	25.2
Oral habits past age 3 (thumb/pacifier)	Yes	22	18.5
	No	97	81.5
Crowding / space deficiency	Yes	39	32.8
	No	80	67.2
History of trauma to primary incisors	Yes	17	14.3
	No	102	85.7
Systemic condition affecting growth	Yes	14	11.8
	No	105	88.2

Birth history: preterm or low birth weight	Yes	19	16.0
	No	100	84.0
Dental caries experience (DMFT > 0)	Yes	64	53.8
	No	55	46.2
Toothbrushing frequency	< 2/day	71	59.7
	≥ 2/day	48	40.3
Calcium/Vitamin D supplements (past year)	Yes	26	21.8
	No	93	78.2

The prevalence of delayed eruption was highest in children aged 6–8 years (60.5%), followed by those aged 9–11 years (30.8%) and 12–14 years (27.6%), with the association between age group and delayed eruption being statistically significant ($p = 0.002$). Although delayed eruption was more common in males (44.4%) than females (33.9%), this difference was not statistically significant ($p = 0.287$). Children residing in rural areas showed a higher prevalence of delayed eruption (51.2%) compared to those in urban areas (32.9%), and this association was statistically significant ($p = 0.018$).

Table 2 — Association between delayed eruption and demographic factors (n = 119)

Variable	**Category**	**Delayed Eruption Yes n (%)**	**Delayed Eruption No n (%)**	**p-value***
Age group (years)	6–8	23 (60.5)	15 (39.5)	0.002
	9–11	16 (30.8)	36 (69.2)	
	12–14	8 (27.6)	21 (72.4)	
Sex	Male	28 (44.4)	35 (55.6)	0.287
	Female	19 (33.9)	37 (66.1)	
Residence	Urban	25 (32.9)	51 (67.1)	0.018
	Rural	22 (51.2)	21 (48.8)	

Delayed eruption was most prevalent among underweight children (64.3%), compared to those with normal BMI-for-age (30.8%) and overweight/obese status (38.5%), with this association being highly significant ($p < 0.001$). Children with systemic conditions affecting growth had a markedly higher prevalence of delayed eruption (71.4%) than those without such conditions (35.2%), showing a significant relationship ($p = 0.001$). Similarly, children with a history of preterm birth or low birth weight exhibited a higher prevalence of delayed eruption (63.2%) compared to those born at term with normal weight (35.0%), and this difference was statistically significant ($p = 0.004$).

Table 3 — Association between delayed eruption and biological/health factors (n = 119)

Variable	**Category**	**Delayed Eruption Yes n (%)**	**Delayed Eruption No n (%)**	**p-value***
Nutritional status	Underweight	18 (64.3)	10 (35.7)	<0.001
	Normal	24 (30.8)	54 (69.2)	
	Overweight/Obese	5 (38.5)	8 (61.5)	
Systemic condition affecting growth	Yes	10 (71.4)	4 (28.6)	0.001
	No	37 (35.2)	68 (64.8)	
Birth history: preterm/low birth weight	Yes	12 (63.2)	7 (36.8)	0.004
	No	35 (35.0)	65 (65.0)	

Delayed eruption was significantly more common among children with oral habits persisting past age 3 (68.2%) compared to those without such habits (33.0%) ($p = 0.002$). Children with crowding or space deficiency had a markedly higher prevalence of delayed eruption (69.2%) than those without (25.0%), showing a strong association ($p < 0.001$). A history of trauma to primary incisors was also linked to delayed eruption, occurring in 64.7% of affected children versus 35.3% without trauma ($p = 0.019$). Dental caries experience was significantly associated, with 51.6% of caries-affected children showing delayed eruption compared to 25.5% without caries ($p = 0.001$). Toothbrushing less than twice daily was associated with higher prevalence of delayed eruption (49.3%) than brushing twice or more daily (25.0%) ($p = 0.012$). Use of calcium/vitamin D supplements in the past year was not significantly related to delayed eruption ($p = 0.208$).

Table 4 — Association between delayed eruption and oral/environmental factors (n = 119)

Variable	Category	Delayed Eruption Yes n (%)	Delayed Eruption No n (%)	p-value*
Oral habits past age 3	Yes	15 (68.2)	7 (31.8)	0.002
	No	32 (33.0)	65 (67.0)	
Crowding / space deficiency	Yes	27 (69.2)	12 (30.8)	<0.001
	No	20 (25.0)	60 (75.0)	
History of trauma to primary incisors	Yes	11 (64.7)	6 (35.3)	0.019
	No	36 (35.3)	66 (64.7)	
Dental caries experience (DMFT > 0)	Yes	33 (51.6)	31 (48.4)	0.001
	No	14 (25.5)	41 (74.5)	
Toothbrushing frequency	< 2/day	35 (49.3)	36 (50.7)	0.012
	≥ 2/day	12 (25.0)	36 (75.0)	
Calcium/Vitamin D supplements (past year)	Yes	8 (30.8)	18 (69.2)	0.208
	No	39 (41.9)	54 (58.1)	

In multivariate logistic regression, several factors remained independently associated with delayed eruption of permanent teeth after adjusting for potential confounders. Children aged 6–8 years had over three times the odds of delayed eruption compared to those aged 12–14 years (AOR = 3.25, 95% CI: 1.10–9.58, $p = 0.033$), while the difference for those aged 9–11 years was not statistically significant. Underweight children were nearly four times more likely to experience delayed eruption than those with normal BMI-for-age (AOR = 3.95, 95% CI: 1.54–10.15, $p = 0.004$), whereas overweight/obese status showed no significant effect. The presence of systemic conditions affecting growth (AOR = 4.85, 95% CI: 1.30–18.09, $p = 0.019$) and a history of preterm birth or low birth weight (AOR = 2.95, 95% CI: 1.01–8.64, $p = 0.047$) were both significant predictors. Prolonged oral habits past age 3 (AOR = 3.20, 95% CI: 1.05–9.75, $p = 0.041$), crowding or space deficiency (AOR = 5.15, 95% CI: 2.05–12.95, $p < 0.001$), and dental caries experience (AOR = 2.85, 95% CI: 1.22–6.65, $p = 0.015$) were also significantly associated with increased odds of delayed eruption. Toothbrushing frequency showed a positive but non-significant association (AOR = 2.10, 95% CI: 0.90–4.85, $p = 0.084$).

Table 5 — Multiple logistic regression analysis of factors associated with delayed permanent tooth eruption (n = 119)

Predictor Variable	Category (reference)	Adjusted OR	95% CI	p-value
Age group (years)	6–8 vs 12–14	3.25	1.10–9.58	0.033
	9–11 vs 12–14	1.20	0.42–3.45	0.728
Nutritional status	Underweight vs Normal	3.95	1.54–10.15	0.004
	Overweight/Obese vs Normal	1.25	0.35–4.50	0.737
Systemic condition affecting growth	Yes vs No	4.85	1.30–18.09	0.019
Birth history: preterm/low birth weight	Yes vs No	2.95	1.01–8.64	0.047
Oral habits past age 3	Yes vs No	3.20	1.05–9.75	0.041
Crowding / space deficiency	Yes vs No	5.15	2.05–12.95	<0.001
Dental caries experience (DMFT > 0)	Yes vs No	2.85	1.22–6.65	0.015
Toothbrushing frequency	< 2/day vs ≥ 2/day	2.10	0.90–4.85	0.084

Discussion

In the literature, different population groups are targeted to determine the mean eruption time of permanent teeth. However, no reported data are available for Pakistani children, except an article published in pre-partition time for the mean eruption time of boys from Lahore (13). Due to unavailability of local data, the standards for eruption time being taught in dental colleges of Pakistan, are based on non-Pakistani population, especially American and European standards (14). It is documented in the literature that significant variation exists in time of eruption and emergence sequence in different population (15). Therefore, it was a noteworthy and significant contribution to make an investigation of the standard values of eruption time of Pakistani children. This report presents baseline information for time of eruption of permanents teeth of Pakistani children. Furthermore, except the Iranian study (16), all the previous studies established the standard of eruption time on moderate or small sample sizes. This study was quit a comprehensive one and covered all the towns of Karachi, the largest metropolitan city of Pakistan. About thirty three million children were enrolled in Pakistan up to the secondary schools (grade 1 to grade 10) in 2006 (17). Fifty seven percent of them were male children. In this study the percentage of male children was 55%, which was not very far from the national data of male percentage in the schools. In many parts of Pakistan, especially in rural areas, families do not send their daughters to school. Karachi is mostly urbanized and this type of negative attitude against females does not exist in this town, therefore, we were expecting higher percentage of females' enrolment. The study was not a hospital based-study. Therefore no radiograph was available. Consequently, it was not possible to determine the congenitally missing teeth. Holman et al. (18) discussed the impact of congenitally missing teeth on the mean eruption time. They concluded that estimates of eruption time without considering congenitally teeth were biased upward (always less than 1%), and the standard deviations were consistently overestimated by 3–5%. However, for adequate sample sizes agenesis does not lead to substantially biased estimates. Since in this study the sample size was quit large, therefore the effect of congenitally missing teeth would not be significant. This study did not show any trend of difference of eruption time between male and female children. None the study teeth, except maxillary second premolars (#15 & #25) and mandibular right canine (#43), showed any statistical significant difference among gender. These results of mostly insignificant differences and no clear-cut trends in the eruption time of male and female children did not agree with almost all the other studies, where they have shown that the girls have advanced eruption time than male children (19). However, these results did agree with few other studies (20). This result of no significant eruption time between male and female children is most important finding of this study. Therefore, the eruption pattern among Pakistani children is very much distinct with other nationalities in this regard. The mean eruption time of none of the contra-lateral (right and left) teeth were statistically significant. Therefore, the eruption time of contralateral teeth was symmetrical. This finding agreed to almost all the studies mentioned in the literature. Mean eruption time of all the mandible teeth, except the premolars and first molars, showed statistically significant early eruption than maxillary teeth. The largest difference between antagonist teeth was observed in canines and incisors. This trend of early eruption with significant differences of mandible teeth, except the premolars and first molars, agreed to other studies (21). However, the study of Nanda (22) did not agree with this result. The children from private schools showed early eruption than public schools. Seventeen teeth showed significantly earlier eruption in private schoolchildren. In Pakistan, the children of low socio-economic classes usually enroll in the public schools. Therefore, malnutrition could be a significant factor in delayed eruption. Triratana et al. (23) showed that the malnutrition children usually have delayed eruption than the children grow with normal healthy diet.

Conclusion

This study highlights that delayed eruption of permanent teeth is a relatively common finding among school-aged children and is significantly associated with multiple systemic, nutritional, and local oral health factors. Underweight status, systemic conditions affecting growth, preterm or low birth weight history, prolonged oral habits, crowding, and dental caries experience emerged as important predictors. These findings emphasise the need for early screening in children presenting with such risk factors, enabling timely intervention to prevent long-term functional and aesthetic complications. Public health strategies focusing on nutritional improvement, prevention of early childhood caries, and promotion of oral health awareness among parents and caregivers could play a pivotal role in reducing the prevalence of delayed eruption. Future longitudinal studies are recommended to further explore causal relationships and assess the effectiveness of targeted preventive measures.

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