Section: Miscellaneous

Original Research Article

ESTIMATION OF AGE FROM PATTERN OF ERUPTION OF PERMANENT TEETH IN CHILDREN IN BORDER DISTRICT OF SOUTH KERALA

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ABSTRACT

Background: Estimation of dental age is an essential component of paediatric dentistry, orthodontics and forensic practice. The eruption of permanent teeth serves as a reliable biological indicator for assessing chronological age in children. However, eruption timing varies with regional, nutritional, environmental and socioeconomic factors, highlighting the need for population-specific reference data. Contemporary data on permanent tooth eruption among children from the border districts of South Kerala are very limited. **Objectives:** The present study aimed to (i) determine the mean age of eruption of permanent teeth among children in the border district of South Kerala and (ii) assess the influence of sex, nutritional status (BMI), socioeconomic status, and arch-wise differences on the eruption pattern.

Materials and Methods: A descriptive cross-sectional study was conducted among 971 school-going children aged 3–18 years in South Kerala. Clinical examination was performed to record the eruption status of permanent teeth. Mean ages of eruption were calculated for individual teeth. Statistical analysis was carried out using STATA version 17. Independent t-tests, paired t-tests and Chi-square tests were applied to evaluate associations between eruption timing and demographic variables. A P-value <0.05 was considered statistically significant.

Results: The mean age of eruption of permanent teeth ranged from approximately 6 to 17 years. First permanent molars were the earliest teeth to erupt, followed by central incisors, while third molars erupted last. Mandibular teeth erupted earlier than their maxillary counterparts with bilateral symmetry in eruption timing. Gender did not statistically influence eruption timing for most permanent teeth; however, first molars erupted significantly earlier in males than females. Nutritional status demonstrated a highly significant association with eruption, with children having normal/high BMI showing earlier eruption compared to underweight children. Poor socioeconomic status was significantly associated with late eruption of teeth such as canines, premolars, second molars and third molars, with earlier eruption observed among children from the Above Poverty Line (APL) group. Eruption status of incisors were same in children of schools.

Conclusion: The eruption pattern of permanent teeth among children in South Kerala follows a sequence comparable to established standards, with only minor regional variations. Nutritional status emerged as the most influential factor affecting tooth eruption, while socioeconomic status played significant roles, particularly for later-erupting teeth. Gender had minimal influence except for first molars. These findings provide updated, region-specific reference data that can enhance the accuracy of dental age estimation in clinical and forensic practice.

Keywords: Dental age estimation; permanent tooth eruption; South Kerala; children; forensic odontology; nutritional status

INTRODUCTION

Identification of individuals, whether living or deceased, forms the foundation of forensic practice and is essential in both civil and criminal investigations. Human identification relies on a combination of biological, physical and behavioural characteristics, including age, sex, stature, dental features, fingerprints and genetic markers. Among these parameters, estimation of age is particularly significant in medicolegal situations such as determination of criminal responsibility, age disputes in juveniles, adoption and immigration cases, child-labour investigations and identification of unknown bodies.[1-3]

Teeth are considered one of the most reliable biological indicators for age estimation, especially valuable in forensic investigations, due to their resistance to decomposition, thermal damage and environmental insults. In children and adolescents, dental age estimation is preferred over skeletal methods, as tooth development and eruption follow a more predictable and genetically regulated pattern compared to physical growth parameters such as height and weight.[1-4]

Dental age estimation in children is commonly based on the stages of tooth formation and the timing of tooth eruption. Among these, the eruption of permanent teeth is widely used in clinical and field settings because it is non-invasive, simple to record and does not require radiographic exposure. The permanent dentition typically begins with the eruption of the first molars and central incisors around six years of age, followed by lateral incisors, premolars, canines and finally second molars during early adolescence. Although the sequence of eruption is relatively constant, the timing of eruption varies across populations.[4,5]

Several studies have demonstrated that the eruption of permanent teeth is influenced by multiple factors, including sex, ethnicity, nutritional status, socioeconomic conditions, systemic health and environmental influences. Girls have been reported to exhibit earlier eruption than boys, likely due to earlier biological maturation. Mandibular teeth generally erupt earlier than their maxillary counterparts, a finding consistently observed across diverse populations. Nutritional deficiencies and lower socioeconomic status have been associated with delayed eruption, while improved nutrition and healthcare access have been linked to earlier dental development.[6-10]

Early Indian studies on tooth eruption provided foundational reference data; however, many of these studies were conducted several decades ago. Since then, significant socioeconomic transitions, urbanization, improved nutritional status and better access to healthcare have contributed to secular changes in growth and development among children. These changes may influence the timing of permanent tooth eruption, rendering older reference standards less applicable to contemporary populations.[11-13]

Kerala has witnessed notable improvements in child health indicators, literacy rates, and socioeconomic conditions over recent decades. Despite this, updated and region-specific data on permanent tooth eruption among children from South Kerala remain limited. Applying eruption standards derived from other regions or older populations may result in inaccuracies in clinical decision-making and age estimation.

In this context, the present study was undertaken to assess the pattern and timing of eruption of permanent teeth among school-going children in border district of South Kerala and to evaluate the influence of sex, nutritional status, socioeconomic status and arch-wise differences in age of eruption. Establishing updated, population-specific eruption data is essential to improve the accuracy of dental age estimation in both clinical and medico legal settings.

MATERIALS AND METHODS

This descriptive cross-sectional study was conducted among school-going children in South Kerala over a period of one year, from August 2024 to August 2025. The study was carried out in selected government, aided and private schools located in both rural and urban areas of southern border part of Thiruvananthapuram district. Ethical clearance for the study was obtained from the Institutional Ethics Committee of the medical college (Approval No: SMCSIMCH/EC(PHARM) 05/01/26 dated 26.07.2024). Permission was obtained from the respective school authorities prior to data collection. Written informed consent was obtained from parents or guardians, and assent was obtained from the children before enrolment in the study. The study included children aged 3–18 years who were permanent residents of South Kerala. Children were eligible for inclusion if they were apparently healthy and had verifiable proof of date of birth through school records or birth certificates. Children with a history of systemic illnesses, congenital or developmental dental anomalies, long-term medication use, premature extraction or loss of primary teeth, orthodontic treatment, or any condition known to affect normal tooth eruption were excluded from the study. A total of 971 children were included in the study. A stratified sampling technique was employed to ensure adequate representation across different age groups and both sexes. Schools were selected to ensure representative samples from varying socioeconomic backgrounds, and participants were proportionately selected from each stratum. Data were collected using a predesigned and pretested structured proforma. Demographic details such as age, sex, type of school (government, aided or private), and socioeconomic status [classified as Above Poverty Line(APL) or Below Poverty Line(BPL)] were recorded. Nutritional status was

assessed using Body Mass Index (BMI), calculated as weight in kilograms divided by height in meters squared (kg/m²), and categorized according to standard age- and sex-specific reference charts. A clinical oral examination was conducted at the school under natural daylight conditions. Sterile mouth mirrors and probes were used for examination of children in a seated position, following standard infection control protocols. The eruption status of permanent teeth central incisors, lateral incisors, canines, premolars, and molars in both maxillary and mandibular arches were assessed. Tooth eruption was defined as the clinical visibility of any portion of the tooth crown emerging through the gingiva. Each tooth was recorded as: 0 – Not erupted, 1 – Erupted. Chronological age was calculated in completed years from the date of birth as entered in school records.

Statistical analysis was done with the help of STATA software version 17. Normality of the data was assessed using Kolmogorov Smirnov test. Values were assessed using mean ± standard deviation. Comparison of Mean age of eruption of permanent teeth between males and females were done using independent t-test. Comparison of Mean age of eruption of permanent teeth between maxilla and mandible were done using Paired t-test. Factors influencing eruption in teeth were done using chi square test. A p-value < 0.05 were considered as statistically significant.

RESULTS

The study population consisted of 971 subjects in the 3 to 18 years age group out of which 494 (50.9%) were males and 477 (49.1%) were females.

The age distribution of participants according to gender is given in Figure 1.

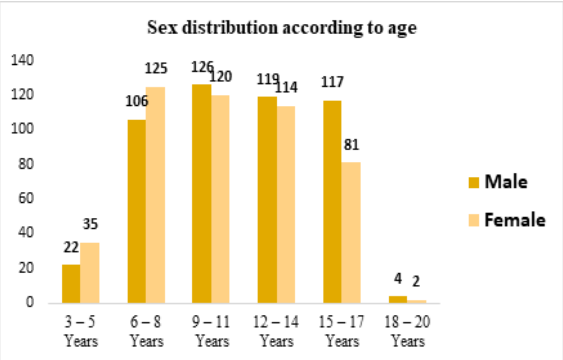

Figure 1: Distribution of gender of study participants based on age

The majority of participants were distributed in the age groups of 6–8 years, 9–11 years, 12–14 years and 15–17 years, with relatively comparable gender representation across these groups. Females (35) outnumbered males in the 3-5 and 6–8 years group, being 35: 22 and 125:106, respectively. However males predominated in the 9–11 and 12–14 years 15–17 years age groups being 126 :100, 119: 114 and 117. 81respectively Only 4 males and 2 females were available for the study in the 18–20 year age group.

The distribution of BMI of male and female participants according to age is given in Figure 2 and 3.

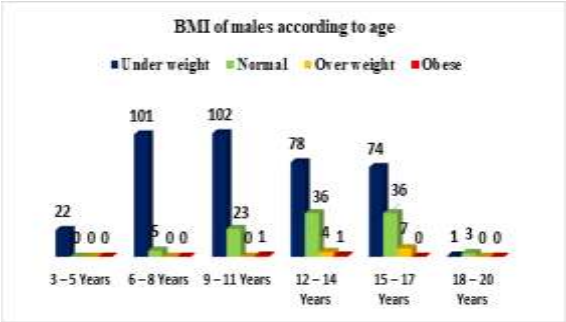

Figure 2: BMI distribution of males according to age group illustrating the distribution of Body Mass Index (BMI) categories among male participants across different age groups.

Males across all age groups were underweight, with a gradual progress to normal and overweight status during adolescence. Obesity was rare.

In the 3–5 years age group, all males were underweight (22). In the 6–8 years age group, the majority were underweight (101), with only a 5 having normal BMI and none classified as overweight or obese.

In the 9–11 years age group, underweight males (102) predominated, with normal BMI observed in 23 children, along with one obese participant. In the 12–14 years age group, underweight males (78) formed the largest group, with 36 numbers showing normal BMI (36), while a few participants were overweight (4) and obese (1).

Among males aged 15–17 years, majority (74) were underweight, with a substantial number having normal BMI (36) and a small proportion being overweight (7); none were obese. Those few males who were in the 18–20 years age group, one was underweight and three had normal BMI; none were overweight or obese participants.

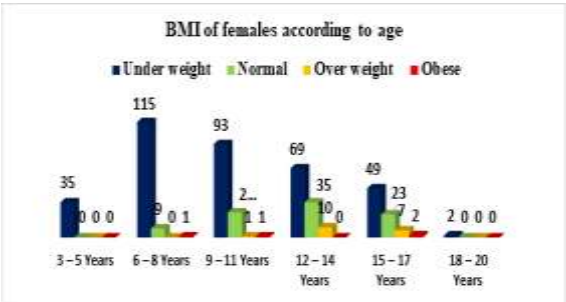

Figure 3: BMI distribution of females according to age group showing the age-wise distribution of Body Mass Index (BMI) categories among female participants

Among females, majority were underweight, with a gradual increase in normal and overweight categories during early and mid-adolescence, while obesity was infrequent.

In the 3–5 years' age group, all females were underweight (35), with none falling into the normal, overweight, or obese categories.
In the 6–8 years' group, the majority were underweight (115), with a small number having normal BMI (9) and one obese participant.
Among females aged 9–11 years, underweight participants (93) were predominant, while a modest increase in normal BMI (22) was observed, along with one overweight and one obese participant.
In the 12–14 years' age group, although underweight females (69) still formed the largest proportion, there was a noticeable increase in normal BMI (35) and overweight (10) categories, but with no obese participants.
In the 15–17 years' age group, underweight females (49) constituted the majority, followed by those with normal BMI (23), overweight (7), and a small number classified as obese (2). Only two females were available for participation in the study, in the 18–20 years' age group, with both being underweight.

Table 1: Classification of gender across various socio economics group according to age, stratified by gender and socioeconomic status [Above Poverty line(APL), Below Poverty line (BPL), and not determinable)

Socioeconomic Group	APL		BPL		Not determinable		Total	
Gender	Male n(%)	Female n(%)	Male n(%)	Female n(%)	Male n(%)	Female n(%)	Male (n)	Female (n)
Age group								
3-5 years	16 (72.73%)	13 (37.14%)	3 (13.64%)	15 (42.86%)	3 (13.64%)	7 (20.00%)	22	35
6-8 years	35 (33.02%)	46 (36.80%)	71 (66.98%)	79 (63.20%)	0	0	106	125
9-11 years	38 (30.16%)	39 (32.50%)	88 (69.84%)	81 (67.50%)	0	0	126	120
12-14 years	60 (50.42%)	78 (68.42%)	52 (43.70%)	28 (24.56%)	7 (5.88%)	8 (7.02%)	119	114
15-17 years	66 (56.41%)	66 (81.48%)	13 (27.35%)	13 (16.05%)	19 (16.24%)	2 (2.47%)	117	81
18-20 years	0	1 (50%)	3 (75%)	1 (50%)	1 (25%)	0	4	2

In the 3–5 years age group, out of total of 57 children, a higher proportion belonged to the APL category (29), followed by BPL (18) and undeterminable (10). Males predominated in the APL group, whereas females were relatively more in the BPL group.
Among children aged 6–8 years, a total of 231 participants were studied, with the majority belonging to the BPL category (150), followed by APL (81). No participants in this age group needed categorization under "undeterminable". Females outnumbered males in both APL and BPL categories.
In the 9–11 years' age group, out of 246 children most belonged to the BPL category (169), while 77 were from the APL group. No participants in this age group needed categorization under "undeterminable". Females constituted a higher proportion in both socioeconomic groups.
The 12–14 years' age group comprised 119 males and 114 females. The majority were from the APL category (138), followed by BPL (80) and "not determinable" (15). Females showed a higher representation in the APL group, whereas males were relatively more in the BPL group.
The 15–17 years' age group, comprised of 198 participants. The majority belonged to the APL category (132), followed by BPL (45) and "not determinable" (21), with females constituting same proportion in both groups.
The 18–20 years' age group had a small sample size of six participants, with most belonging to the BPL category (4), followed by APL (1) and "not determinable" (1).

Table 2: Classification of types of school across various age groups according to the type of school attended, namely private, aided and Government schools

Age Group	Schools			Total [n=971]
	Private n (%)	Aided n (%)	Government n (%)	
3 – 5 Years	18 (31.58%)	5 (8.77%)	34 (59.65%)	57
6 – 8 Years	25 (10.82%)	128 (55.41%)	78 (33.77%)	231
9 – 11 Years	46 (18.70%)	131 (53.25%)	69 (28.05%)	246
12 – 14 Years	21 (9.01%)	65 (27.90%)	147 (63.09%)	233
15 – 17 Years	0	25 (12.63%)	173 (87.37%)	198
18 – 20 Years	0	0	6 (100%)	6

In the 3–5 years age group (n = 57), the majority of children enrolled were students of Government schools (34; 59.65%), remaining drawn from private schools (18; 31.58%) and aided schools (5; 8.77%).

Among children aged 6–8 years (n = 231), students from aided schools accounted for the largest proportion (128; 55.41%), followed by those from government schools (78; 33.77%) and private schools (25; 10.82%).

In the 9–11 years' age group (n = 246), most participants were from aided schools (131; 53.25%), followed by government schools (69; 28.05%) and private schools (46; 18.70%).

For the 12–14 years' age group (n = 233), government schools constituted the majority (147; 63.09%), while aided schools accounted for 65 (27.90%) and private schools for 21 (9.01%).

In the 15–17 years' age group (n = 198), a predominant proportion of participants were studying in government schools (173; 87.37%), followed by aided schools (25; 12.63%). No participants in this age group were enrolled in private schools.

The 18–20 years' age group had a very small sample size (n = 6), with all participants enrolled in government schools (100%).

Table 3: Mean age of eruption of teeth (± SD) of eruption of permanent teeth on the right and left sides in both maxillary and mandibular arches

Tooth erupted	Maxillary		Mandibular	
	Right	Left	Right	Left
Central Incisor	7.61 ± 0.58	7.59 ± 0.60	7.36 ± 0.75	7.67 ± 0.76
Lateral Incisor	8.57 ± 0.63	8.58 ± 0.64	8.31 ± 0.75	8.34 ± 0.74
Canine	11.31 ± 0.74	11.32 ± 0.73	11.15 ± 0.79	11.19 ± 0.77
First Premolar	10.48 ± 0.60	10.50 ± 0.60	10.54 ± 0.57	10.51 ± 0.63
Second Premolar	11.34 ± 0.81	11.34 ± 0.77	11.32 ± 0.77	11.36 ± 0.76
First Molar	6.78 ± 0.45	6.77 ± 0.45	6.74 ± 0.46	6.73 ± 0.47
Second Molar	13.22 ± 0.86	13.19 ± 0.88	13.12 ± 0.92	13.14 ± 0.93
Third Molar	16.67 ± 0.49	16.61 ± 0.51	16.64 ± 0.49	16.83 ± 0.38

Overall, the eruption ages of corresponding right and left teeth are very similar, indicating bilateral symmetry in tooth eruption.

The first permanent molar was the earliest tooth to erupt, with mean ages around 6.7–6.8 years in both arches. This was followed by the central incisors, which erupted earlier in the mandibular arch (≈7.3–7.7 years) compared to the maxillary arch (≈7.6 years). Lateral incisors erupted next, with mandibular lateral incisors showing slightly earlier eruption than maxillary lateral incisors.

The first premolars erupted at around 10.5 years, followed by the canines at approximately 11.1–11.3 years, with mandibular canines erupting marginally earlier than maxillary canines. Second premolars erupted around 11.3–11.4 years, showing minimal side and arch differences.

The second molars erupted at approximately 13.1–13.2 years, while the third molars were the last to erupt, with mean ages ranging from 16.6 to 16.8 years. Slight variations were observed between arches and sides, but these differences were minimal.

Table 4: Comparison of Mean age of eruption of permanent teeth between males and females for the right and left sides of the maxillary and mandibular arches

Teeth	Mean Age ± SD				t-value		p-value		CI	
	Male		Female							
	Right	Left	Right	Left	Rt	Lt	Rt	Lt	Rt	Lt
CI (Maxillary)	7.57 ± 0.67	7.66 ± 0.52	7.64 ± 0.51	7.55 ± 0.65	-0.65	0.95	0.11	0.08	-0.3 – 0.15	-0.11 – 0.32
CI(Mandibular)	7.94 ± 0.98	7.92 ± 0.99	8.01 ± 0.90	8.02 ± 0.90	-0.64	-0.84	0.15	0.09	-0.31 – 0.16	-0.33 – 0.14
LI (Maxillary)	8.59 ± 0.65	8.6 ± 0.66	8.57 ± 0.62	8.58 ± 0.63	0.19	0.23	0.88	0.92	-0.2 – 0.24	-0.2 – 0.26
LI (Mandibular)	8.37 ± 0.75	8.38 ± 0.73	8.28 ± 0.76	8.30 ± 0.75	0.78	0.72	0.85	0.84	-0.14 – 0.31	-0.14 – 0.29
Canine (Maxillary)	11.4 ± 0.7	11.37 ± 0.72	11.24 ± 0.77	11.27 ± 0.75	1.09	0.74	0.58	0.83	-0.13 – 0.45	-0.18 – 0.38
Canine (Mandibular)	11.24 ± 0.75	11.25 ± 0.74	11.08 ± 0.81	11.14 ± 0.79	1.14	0.81	0.61	0.51	-0.11 – 0.42	-0.15 – 0.36
IPM (Maxillary)	10.5 ± 0.58	10.51 ± 0.63	10.47 ± 0.63	10.49 ± 0.59	0.26	0.17	0.59	0.68	-0.22 – 0.3	-0.23 – 0.27
IPM (Mandibular)	10.6 ± 0.55	10.53 ± 0.65	10.5 ± 0.59	10.49 ± 0.63	0.85	0.27	0.36	0.88	-0.15 – 0.37	-0.25 – 0.32
IIPM (Maxillary)	11.33 ± 0.81	11.3.7 ± 0.7	11.36 ± 0.80	11.3 ± 0.81	-0.13	0.43	0.82	0.56	-0.35 – 0.31	-0.24 – 0.37
IIPM (Mandibular)	11.38 ± 0.71	11.4 ± 0.7	11.26 ± 0.85	11.32 ± 0.84	0.78	0.52	0.2	0.17	-0.18 – 0.43	-0.23 – 0.39
IM (Maxillary)	6.72 ± 0.51	6.71 ± 0.51	6.84 ± 0.37	6.84 ± 0.37	-1.22	-1.3	**0.014**	**0.011**	-0.33 – 0.08	-0.34 – 0.07
IM (Mandibular)	6.67 ± 0.52	6.66 ± 0.53	6.81 ± 0.39	6.8 ± 0.41	-1.49	-1.42	**0.003**	**0.005**	-0.34 – 0.05	-0.34 – 0.56
IIM (Maxillary)	13.25 ± 0.78	13.2 ± 0.84	13.2 ± 0.92	13.2 ± 0.92	0.55	0.05	0.06	0.15	-0.18 – 0.32	-0.24 – 0.26

IIM (Mandibular)	13.12 ± 0.89	13.17 ± 0.88	13.12 ± 0.96	13.13 ± 0.97	0.01	0.34	0.33	0.26	-0.26 – 0.26	-0.22 – 0.31
IIIM (Maxillary)	16.7 ± 0.48	16.7 ± 0.48	16.5 ± 0.71	16.4 ± 0.57	0.51	1.11	0.58	0.85	-0.68 – 1.1	-0.36 – 1.1
IIIM (Mandibular)	16.8 ± 0.41	16.9 ± 0.34	16.4 ± 0.52	16.7 ± 0.48	2.15	0.91	0.07	0.1	0.01 – 0.78	-0.21 – 0.53

Independent t-tests were used to assess gender differences, and their corresponding p-values and 95% confidence intervals (CI). Overall, most teeth showed no statistically significant difference in mean eruption age between males and females ($p > 0.05$), as the confidence intervals included zero.

For central incisors (CI), lateral incisors (LI), canines, first premolars (I PM), second premolars (II PM), second molars (II M), and third molars (III M), no significant gender difference was observed on either side of the maxilla or mandible.

Females generally exhibited a slightly earlier mean eruption age for several teeth, but these differences were not statistically significant.

A statistically significant difference was noted only for the first molars (I M): Maxillary first molars (right and left) showed significantly earlier eruption in males compared to females ($p = 0.014$ and 0.011, respectively). Mandibular first molar (right and left) also demonstrated a significant gender difference, with teeth of males erupting earlier than females ($p = 0.003$ and 0.005, respectively).

Factors Influencing Eruption of Permanent Teeth

The association between factors like gender, body mass index (BMI), and socioeconomic status, (type of school indirectly indicating economic status) and the eruption of permanent teeth - incisors, canines, premolars, and molars in both maxillary and mandibular arches on the right and left sides were assessed using the Chi-square test.

Gender: Gender did not show a consistent statistically significant association to timing of eruption for most teeth. For central and lateral incisors, both maxillary and mandibular, the differences between males and females were not statistically significant ($p > 0.05$).

However, a significant association with male predominance was observed for Maxillary and mandibular first molars.

The findings indicate that gender has minimal influence on the eruption timing of most permanent teeth, except for first molars, which erupt significantly earlier in males in both arches.

BMI emerged as the most influential factor affecting permanent tooth eruption.

Body Mass Index (BMI): BMI showed a highly significant association with eruption status across all permanent teeth ($p < 0.001$), children with normal BMI consistently exhibiting the highest proportion of early erupted teeth, followed by overweight and obese categories. In contrast, underweight children showed delay in eruption, with a markedly higher proportion of late eruption across all incisors (central and lateral), Canines, first and second premolars and molars in both arches.

Socioeconomic Status- Socioeconomic status demonstrated a significant association with eruption for canines, premolars, second molars, and third molars ($p < 0.001$).

Children belonging to the Above Poverty Line (APL) group showed a significantly higher proportion of early eruption of teeth, while those from the Below Poverty Line (BPL) group exhibited delayed eruption.

For incisors and first molars, the association with socioeconomic status was not consistently significant ($p > 0.05$), suggesting that socioeconomic influence becomes more pronounced for later-erupting teeth.

Type of School education- With regard to all teeth except early erupting incisors, the type of school (indirectly depicting the economic status) showed a statistically significant association in eruption status, with consistently upper age limit in eruption noticed among children attending Government schools, followed by aided schools, and lower age limits among private school students ($p < 0.01$).

DISCUSSION

Estimation of age in children using dental parameters remains a cornerstone of forensic odontology and paediatric dental practice. Among the available methods, assessment of permanent tooth eruption is widely accepted because it is simple, non-invasive and does not require radiographic exposure. The present study provides updated, region-specific data on the pattern and timing of permanent tooth eruption among children from the border district of South Kerala and evaluates the influence of biological and socioeconomic factors on eruption timing.

Pattern and Sequence of Permanent Tooth Eruption

The sequence of eruption observed in the present study largely conforms to the classical eruption chronology described in standard dental literature, with the first permanent molars and central incisors erupting earliest, followed by lateral incisors, premolars, canines and finally the second and third molars. This consistency in eruption sequence supports the concept that tooth eruption is a genetically regulated process, with relatively stable sequencing across populations.

However, minor variations in the timing of eruption were observed when compared to earlier Indian and international studies.[13-15] Such differences are likely attributable to high literacy status, secular trends, regional diversity and improvements in nutrition and healthcare access in the state of Kerala over recent decades. The mean age of eruption noted in this study provide contemporary reference values that are more

applicable to children in South Kerala than older eruption standards derived from different populations.

Arch-wise and Side-wise Differences

A consistent finding in the present study was the earlier eruption of mandibular teeth compared to their maxillary counterparts. This observation aligns with reports from multiple Indian and global studies, reinforcing the notion that mandibular teeth generally erupt earlier due to differences in jaw growth patterns, bone density and eruption pathways.[13-15] Additionally, the eruption ages of corresponding right and left teeth were nearly identical, demonstrating bilateral symmetry. This symmetry supports the reliability of eruption timing as a biological indicator and suggests that unilateral eruption delays should prompt clinical evaluation rather than be considered normal variation.

Influence of Gender on Tooth Eruption

In the present study, gender did not show a statistically significant influence on the eruption timing of most permanent teeth. Although females tended to exhibit slightly earlier eruption for several teeth, these differences were not statistically significant. This finding contrasts with many earlier studies that have reported earlier dental maturation in girls, often attributed to earlier pubertal and skeletal development.

A statistically significant gender difference was observed only for the first permanent molars, which erupted earlier in males than females in both maxillary and mandibular arches. This finding deviates from commonly reported trends and may reflect population-specific growth patterns or environmental influences.[16] It also underscores the importance of using region-specific data rather than assuming uniform gender differences across populations.

Gender discrimination in providing nutrition is almost a nonentity in this highly literate part of India.

Effect of Nutritional Status (BMI)

Nutritional status, assessed using BMI, emerged as the most influential factor affecting the eruption of permanent teeth in this study. Children with normal BMI demonstrated significantly earlier eruption across all tooth groups, whereas underweight children showed a marked delay in eruption. This strong association is biologically plausible, as adequate nutrition is essential for normal growth, mineralization and dental development.

The consistent delay in eruption observed among underweight children highlights the impact of chronic undernutrition on dental maturation. These findings are in agreement with previous studies that have reported delayed tooth eruption in children with poor nutritional status.[14] The results emphasize the need to consider nutritional status when interpreting dental age, particularly in medicolegal cases involving children from socioeconomically disadvantaged backgrounds.

Influence of Socioeconomic Status

Socioeconomic status showed a significant association with the eruption of later-erupting teeth, including canines, premolars, second molars, and third molars. Children from the Above Poverty Line group exhibited earlier eruption compared to those from the Below Poverty Line group. This trend may be attributed to better access to nutrition, healthcare services, and overall living conditions among children from higher socioeconomic strata.[14]

Interestingly, socioeconomic status did not show a consistent influence on the eruption of early-erupting teeth such as incisors and first molars. This may be because early erupting teeth are more strongly governed by genetic factors and the social priorities given for the welfare of lactating mothers and preschool children through welfare schemes of the state, while later erupting teeth were more susceptible to environmental and socioeconomic influences accumulated over time.

Type of School as an indicator

The type of school (an indirect indicator of the economic status) attended showed a statistically significant association, with late eruption status for most teeth, except for incisors which showed no significant correlation. Children attending Government schools demonstrated a delay in eruption compared to those in aided and private schools. This finding may reflect underlying differences in dental maturation lack of nutritional supplementation and specific socioeconomic composition rather than the school type itself.[14] The lack of association for timely eruption of incisor teeth supports the idea that environmental influences exert effect on later stages of dental development.

Forensic and clinical implications

The findings of this study have important implications for forensic age estimation. The observed influence of BMI and socioeconomic status suggests that reliance on standard eruption charts without considering contextual factors may lead to over- or under-estimation of age. The region-specific eruption data generated in this study can improve the accuracy of age estimation in children from South Kerala, particularly in legal scenarios involving age disputes.

Limitations

The study has certain limitations. Being cross-sectional in design, it provides a snapshot of eruption timing rather than individual longitudinal patterns. Radiographic assessment of tooth development was not performed, which may have provided supplementary or complementary information. Additionally, the relatively small number of participants in the oldest age group due to better educational results in central and state board examinations may limit the generalizability of findings related to third molars.

Future Directions

Longitudinal studies incorporating radiographic methods could provide deeper insights into the determinants of dental maturation. Further multicentric studies across different regions of Kerala

and India are recommended to develop comprehensive national reference standards for dental age estimation.

CONCLUSION

The present study provides updated, region-specific data on the eruption pattern of permanent teeth among children in the border district of South Kerala. The sequence of eruption largely followed established dental standards, with first permanent molars and incisors erupting earliest and third molars erupting last. Mandibular teeth erupted earlier than maxillary teeth, and bilateral symmetry in eruption timing was observed. Gender showed minimal influence on tooth eruption, except for first molars, which erupted significantly earlier in males. Nutritional status emerged as the most significant determinant of eruption timing, with delayed eruption observed consistently among underweight children. Socioeconomic status significantly influenced the eruption of later-erupting teeth, with earlier eruption seen in children from the Above Poverty Line group. These findings emphasize the need to consider nutritional and socioeconomic factors in dental age estimation and provide contemporary, population-specific reference data useful for clinical and forensic practice in South Kerala.

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