



QUADRANT-SPECIFIC ERUPTION PATTERN AND ODONTOMETRIC CHARACTERISTICS OF PERMANENT CANINES AMONG SOUTH INDIAN SCHOOLGIRLS AGED 9–13 YEARS

Sreechithra P Karippuram^{1*}, Santhosh Joy², Sreelekshmi J³, Sreelal T P⁴, Thomas Mathew⁵, Sudha S⁶

^{1*}Assistant Professor and Assistant Police Surgeon, Department of Forensic Medicine, Government Medical College, Kottayam, Kerala, India – 686008.

²Associate Professor, Department of Forensic Medicine, Ernakulam Medical College, Kalamassery, Ernakulam, Kerala, India – 683503.

³Assistant Professor, Department of Forensic Medicine and Toxicology, Lady Hardinge Medical College, New Delhi, India – 110001.

⁴Clinical Professor, Manipal University College Malaysia (MUCM), Malaysia – 84000.

⁵Professor and Head, Department of Forensic Medicine and Toxicology, Malabar Medical College and Research Centre, Calicut, Kerala, India.

⁶Professor and Head, Department of Oral Pathology, Government Dental College, Calicut, Kerala, India.

Corresponding Author: Dr. Sreelekshmi J

Assistant Professor, Department of Forensic Medicine and Toxicology, Lady Hardinge Medical College, New Delhi, India– 110001.

Email: jsreelekshmij@gmail.com

ABSTRACT

Introduction: Among all permanent teeth, canines hold particular forensic significance owing to their strong crown morphology, resistance to destruction, late eruption, and lifelong retention. Clinical assessment of canine eruption status is a reliable and radiation-free method of estimating age during the mixed dentition stage. Since there is variation in the eruption of canine teeth among different populations and sexes, the present study was designed to evaluate the eruption pattern, stages of eruption, and morphological and odontometric features of permanent canine teeth among 9-13 year-old South Indian schoolgirls

Materials and Methods: A cross-sectional observational study was conducted among 600 school-going girls from Kozhikode district of Kerala. Equal numbers of girls were divided into four age groups: 9-10 years, 10-11 years, 11-12 years, and 12-13 years. Each group consisted of 150 school-going girls. Clinical dental examination was performed during school hours using a dental mirror and torch. The status of permanent canine eruption was noted for all four quadrants. Canine morphology was classified into incisor-like, regular canine, and premolar-like types. Mesiodistal width, cervico-incisal height, and intercanine width were measured using a vernier caliper. Chi-square test and descriptive statistics were used for analysis.

Results: Mandibular canines erupted earlier than maxillary canines, with the right mandibular canine being the earliest, at 3.3% of 9–10 years of age and 82.0% of 10–11 years of age. At 11–12 years of age, the eruption of the right lower canine was nearly complete (97.3%), whereas the left lower canine erupted at 92.7%. The right maxillary canine erupted last among the four teeth, at 35.3% of 12–13 years of age. Typical canine morphology was more common among younger female individuals, and there was a gradual progression towards incisor-like and then premolar-like morphology with increasing age. Dimensions of odontometric features showed a gradual increase, and cervico-incisal length approached mesiodistal length at ages 12-13 years.

Conclusion: Permanent canine eruption among South Indian schoolgirls exhibits a specific pattern along the quadrants, along with specific age-related morphological and odontometric changes. These results provide sex-specific reference values for improving the accuracy of age estimation and have further implications for bite mark analysis.

Keywords: Forensic Odontology, Age Estimation, Permanent Canine, Dental Eruption, Girls.



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INTRODUCTION

Forensic odontology is a developing branch of forensic sciences that applies dental knowledge to medico-legal investigations, including identification of individuals, analysis of bite marks, maintenance of legally admissible dental records, and age estimation (1). Among these applications, age estimation in children and adolescents is of particular importance, as legal responsibility, consent, and judicial outcomes are closely related to chronological age.

Teeth possess unique forensic value due to their resistance to decomposition and their ability to withstand high temperatures without significant alteration in microstructure. Williams reported that enamel and dentin lose structural integrity only at extremely high temperatures, emphasizing the reliability of dental tissues in forensic identification (1). The eruption pattern, morphology, position, and arrangement of teeth vary among individuals and populations, further enhancing their medico-legal significance.

In living individuals, age estimation relies on physical, dental, and radiological parameters. Dental development is considered a relatively stable biological indicator and is less influenced by environmental factors than skeletal maturation. The best method to calculate the age in children is the eruption pattern of teeth. Tooth eruption and calcification are the two principal dental events used in age estimation during childhood.

Humans exhibit diphyodont dentition, consisting of deciduous and permanent teeth. The mixed dentition period extends approximately from 6 to 12 years of age, during which deciduous teeth are replaced by permanent successors. Permanent canines erupt between 9 and 12 years and are particularly useful for age estimation during this period (2). Previous studies have demonstrated variations in eruption timing among different ethnic and geographic populations. Females have been reported to exhibit earlier eruption of permanent teeth than males in several populations. The relationship between nutritional status, including body mass index, and tooth eruption has also been explored, with inconsistent findings. These observations highlight the need for population- and sex-specific eruption data (3–6). The basic concept of forensic odontology centres on the recognition and comparison of dental patterns (7). There are no significant relationship with dental development and maturity indicators (8). These findings are relevant for both medico-legal work and dental treatment planning.

The age range chosen has immense medico-legal significance. Offences against persons of this age are reported frequently. Separation of a child under the age of 10 years from lawful guardianship would amount to kidnapping and any further movement of the child would add up as additional offence of

abduction (sec. 369 I.P.C) (9). Criminal responsibility of a child above 12 years explained under section 83 I.P.C. A child above 12 years is considered to be mature enough to have the power of understanding the difference between truth and falsehood and hence has to take oath before giving evidence (Indian oath amendment act 1939). Further he acquires the right to discuss his illness and treatment with his doctor and consent for non-invasive treatment of a child of this age is socially and legally recognized (sec 89 I.P.C) (9).

Objective

To evaluate the eruption pattern, timing, and morphological characteristics of permanent maxillary and mandibular canine teeth among school-going girls aged 9–13 years.

MATERIALS AND METHODS

Study Design and Setting: A cross-sectional observational study was conducted by the Department of Forensic Medicine, Government Medical College, Kozhikode in collaboration with dental specialists among school-going girls in Kozhikode district, Kerala.

Study Population and Sample Size: A total of 600 school-going girls aged 9–13 years were included in the final analysis after excluding participants who did not meet inclusion criteria. Participants were stratified equally into

four age groups of 150 each: 9–10, 10–11, 11–12, and 12–13 years. Age was calculated from verified dates of birth recorded in school registers.

Inclusion and Exclusion Criteria: Girls aged 9–13 years with documented dates of birth and without systemic illness, craniofacial anomalies, retained deciduous canines, major dental procedures, or history of dental trauma were included. Participants with unreliable or undocumented age records were excluded.

Data Collection and Dental Examination: Clinical examination was conducted during school hours using a dental mirror and torch. A permanent canine was recorded as erupted when any portion of the crown had penetrated the gingival margin. All four quadrants were examined systematically. Additional information collected included dental hygiene status, dietary habits, and history of systemic illness.

Eruption Stage Classification: Eruption stages were classified as Stage A (eruption of the first premolar together with all permanent incisors and the first molar), Stage B (eruption of the second premolar in addition to Stage A), and Stage C (eruption of permanent canine teeth). Subcategories 1, 2, and 3 denote eruption in the lower jaw, upper jaw, and either jaw, respectively. Stages C4, C5, and C6 indicate canine eruption in the lower jaw, upper

jaw, and either jaw, respectively, preceding second premolar eruption.

Morphological and Odontometric Assessment: Canine morphology was classified into three types: incisor-like (parabolic outline), typical canine (conical form), and premolar-like (square-cut appearance). Mesiodistal length (MDL), cervico-incisal length (CIL), and intercanine distance (ICD) were measured in millimetres using a vernier caliper.

Ethical Considerations: The study was approved by the Institutional Ethics Committee of Government Medical College, Kozhikode, and conducted in accordance with the Declaration of Helsinki. Approval was obtained from the District Education Officer and school authorities. Written informed consent was obtained from parents or legal guardians, and assent was obtained from participants prior to examination.

Statistical analysis: Data were compiled and analysed using jamovi statistical software (version 2.6.45.0). Categorical variables are expressed as frequencies and percentages; continuous variables as mean $\pm$ standard deviation. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1. Age-Wise Eruption of Permanent Canines by Quadrant in Girls (N=600)

Age group (Yrs)	Right Upper n (%)	Left Upper n (%)	Right Lower n (%)	Left Lower n (%)
9–10	0 (0)	0 (0)	5 (3.3)	0 (0)
10–11	4 (2.7)	9 (6.0)	123 (82.0)	78 (52.0)
11–12	5 (3.3)	20 (13.3)	146 (97.3)	139 (92.7)
12–13	53 (35.3)	133 (88.7)	148 (98.7)	146 (97.3)

Overall Prevalence of Canine Eruption: The overall prevalence of at least one erupted permanent canine increased progressively with age. In the 9–10 year group, only 3.3% of girls showed any erupted canine. This rose sharply to 95.3% in the 10–11 year group and reached 100% by 11–12 years, remaining complete through 12–13 years (Table 1).

Stages of Eruption Pattern: Eruption stage classification revealed a consistent age-related progression. In the 9–10 year group, Stage A3 was

A total of 600 school going girl children aged 9–13 years were included in the final analysis, with 150 participants in each age group.

Quadrant-wise Eruption Pattern: Mandibular canines erupted earlier than maxillary canines in all age groups. The right mandibular canine was the first to erupt, observed in 3.3% of girls aged 9–10 years. Eruption prevalence increased markedly to 82.0% in the 10–11 year group and reached near-completion at 97.3% by 11–12 years and 98.7% by 12–13 years. The left mandibular canine was not observed to erupt before 10 years; eruption was documented in 52.0% of girls in the 10–11 year group and in 92.7% by 11–12 years (Table 1). The left maxillary canine erupted later, with 6.0% eruption in the 10–11 year group, 13.3% in the 11–12 year group, and 88.7% by 12–13 years. The right maxillary canine was the last to erupt across all quadrants; no eruption was observed before 11 years and only 35.3% of girls had completed its eruption by 12–13 years, indicating that this tooth's emergence extends beyond the observation period for the majority of the study population (Table 1). The overall eruption sequence was therefore: right mandibular, left mandibular, left maxillary, right maxillary.

the predominant pattern (86.7%), indicating that eruption of the first premolar and incisors was complete but canine eruption had not yet begun in the majority of girls. By 10–11 years, Stage C4 dominated (87.3%), indicating mandibular canine eruption preceding second premolar eruption. In the 11–12 year group, Stage C4 remained the most common (70.0%) with a notable rise in Stage C3 (9.3%). By 12–13 years, Stage C3 was the clear predominant pattern (84.0%), reflecting eruption of canines in both jaws. Table 2 presents the complete stage distribution.

Table 2. Stage of Eruption Pattern in Girls (N=600)

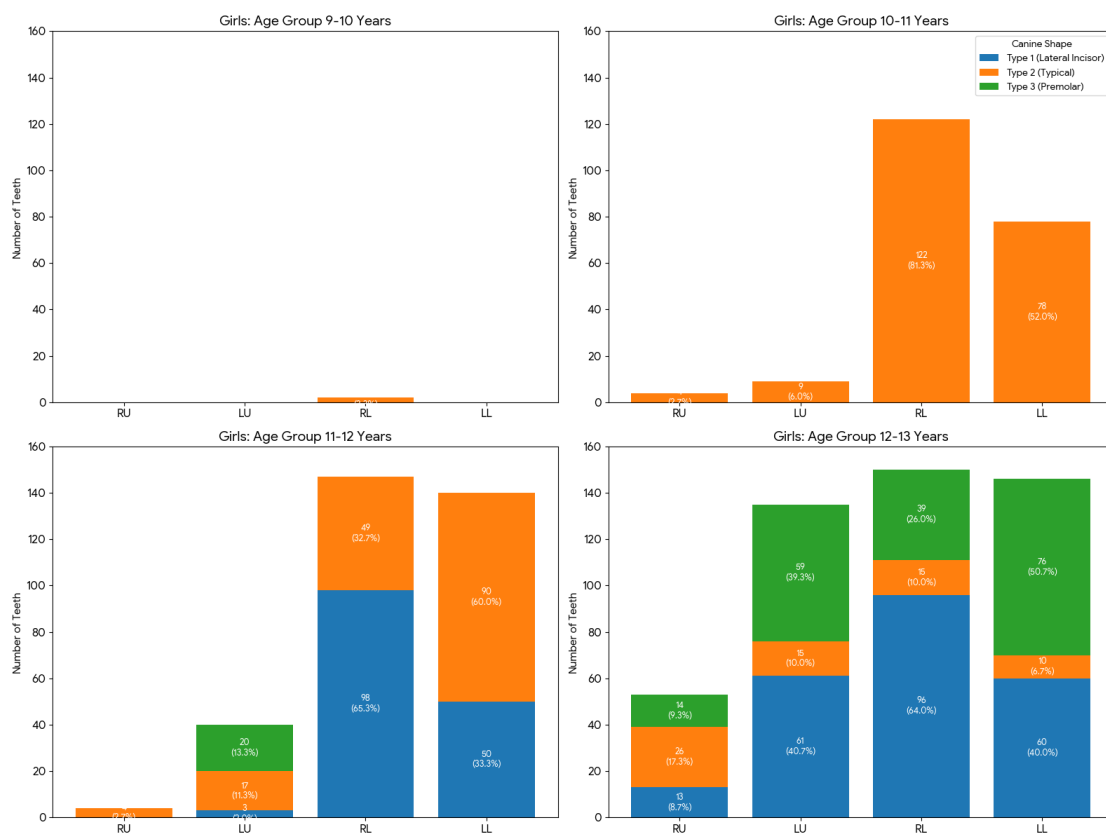
Stage	Group I 9–10 yrs n (%)	Group II 10–11 yrs n (%)	Group III 11–12 yrs n (%)	Group IV 12–13 yrs n (%)
A1	10 (6.7)	3 (2.0)	—	—

A2	5 (3.3)	2 (1.3)	—	—
A3	130 (86.7)	1 (0.7)	—	—
B1	—	—	—	—
B2	—	—	—	—
B3	—	—	—	1 (0.7)
C1	—	—	22 (14.7)	11 (7.3)
C2	—	—	—	5 (3.3)
C3	—	2 (1.3)	14 (9.3)	126 (84.0)
C4	5 (3.3)	131 (87.3)	105 (70.0)	—
C5	—	3 (2.0)	—	—
C6	—	8 (5.3)	9 (6.0)	7 (4.7)

Stage A = eruption of first premolar with all permanent incisors and first molar. Stage B = Stage A + second premolar. Stage C = canine eruption. Subcategories 1/2/3 = lower/upper/either jaw. C4/C5/C6 = canine eruption before second premolar in lower/upper/either jaw.

Morphological Characteristics: The morphology of erupting permanent canines demonstrated a consistent age-related progression. In the 9–10 year group, all five erupted canines in the right lower quadrant displayed typical canine (conical) form. In the 10–11 year group, typical canine morphology remained predominant across erupted teeth (81.3% right lower; 52.0% left lower). A progressive shift toward incisor-like (parabolic) morphology was observed in the 11–12 year group:

65.3% of right lower canines and 33.3% of left lower canines showed incisor-like form, while 13.3% of left upper canines had transitioned to premolar-like form. By 12–13 years, premolar-like (square-cut) morphology became dominant in the lower and left upper quadrants, while incisor-like form also increased substantially. This morphological progression is attributed to the cumulative effect of occlusal loading and interproximal attrition once the tooth is in function (Figure 1).



RU=Right upper; LU=Left upper; RL=Right lower; LL=Left lower. Type 1=incisor-like (parabolic); Type 2=typical canine (conical); Type 3=premolar-like (square-cut). *n=5 erupted in Group I right lower; percentage is of erupted teeth only.

Figure 1: Age-Wise and Quadrant-Wise Distribution of Morphological Types of Permanent Canines in Girls (N=600)

Odontometric Measurements: Both mesiodistal length and cervico-incisal length increased progressively with age in all quadrants where measurements were obtainable. In the 9–10 year group, measurements were available only for the right lower canine, the only tooth erupted in that group. By 12–13 years, both dimensions had increased sub-stantially. Notably, cervico-incisal length approached and, in the right lower quadrant, exceeded mesiodistal length - a pattern that is the reverse of that seen in younger children where mesiodistal length is greater. This convergence,

observed here between 12 and 13 years, marks the transition toward the adult dental pattern and reflects increasing clinical crown exposure as eruption advances.

Inter canine distance was greater in the upper jaw than in the lower jaw at all measured age groups, with the upper-to-lower jaw difference approximating 0.5–0.8 mm in the 12–13 year group. This consistent differential has direct forensic relevance in bite mark analysis, enabling determination of jaw of origin from bite mark dimensions (Table 3).

Table 3. Odontometric Measurements of Permanent Canines in Girls (Mean $\pm$ SD, Mm)

Measure	Jaw	Group I 9–10 Mean (SD)	Group II 10–11 Mean (SD)	Group III 11–12 Mean (SD)	Group IV 12–13 Mean (SD)
MDL	RU	—	2.60 (0.46)	2.40 (0.24)	3.30 (0.29)
	LU	—	2.52 (0.39)	2.48 (0.20)	4.11 (0.28)
	RL	2.28 (0.11)	3.12 (0.42)	2.91 (0.22)	6.07 (0.99)
	LL	—	2.81 (0.35)	2.49 (0.23)	5.20 (0.94)
CIL	RU	—	1.55 (0.19)	1.20 (0.14)	2.51 (0.36)
	LU	—	1.64 (0.28)	1.23 (0.14)	4.02 (1.29)
	RL	1.28 (0.11)	1.62 (0.30)	2.26 (0.31)	6.15 (1.46)
	LL	—	1.41 (0.27)	1.99 (0.32)	4.95 (1.55)
ICD	Upper jaw	—	—	3.40 (0.21)	3.22 (0.21)
	Lower jaw	—	2.72 (0.18)	2.65 (0.13)	2.65 (0.83)

MDL=Mesiodistal length; CIL=Cervico-incisal length; ICD=Inter canine distance. RU=Right upper; LU=Left upper; RL=Right lower; LL=Left lower. All values in mm. — indicates insufficient eruption for measurement in that age group.

DISCUSSION

Estimation of age in medico-legal cases relies on the assessment of physical, dental, and radiological parameters. Dental development has been recognized as a sensitive method of age estimation of living individuals, the deceased, and skeletal remains (2). According to Williams, the deterioration of the structure of enamel and dentine begins at temperatures above 800 degrees Celsius, which proves the strength of dental evidence as a tool of forensic analysis (1). During the growing years, the eruption of teeth provides a reasonably accurate estimation of age. The clinical assessment of tooth eruption is advantageous, especially in living persons, as it does not expose them to

ionizing radiation as required by radiographic examination (10).

Tooth eruption is a continuous process, not a discrete event, which is affected by both genetic and environmental factors. Previous studies have presented different conclusions regarding the effects of environmental factors, with some indicating that tooth eruption is relatively independent of these factors (10). The eruption of each tooth has a unique eruption pattern, with permanent canine teeth, which appear during the late mixed dentition period, playing a critical role as indicators of age estimation.

Pattern of Eruption of Permanent Canine Teeth in Girls: The current study has shown a consistent

quadrant-specific pattern in the eruption of permanent canine teeth in South Indian schoolgirls. The eruption of right maxillary canine was the first to occur, with 3.3% girls showing eruption at the age of 9–10 years. The eruption showed a marked increase in the 10–11 years age group, with 82.0% showing eruption by the end of 10 years. The eruption of the right mandibular canine tooth was almost complete in the 11–12 years age group, with 97.3% showing eruption, thus indicating the critical period to be between 10 and 11 years. The eruption of the left mandibular canine tooth occurred after the right mandibular canine tooth, with no eruption observed in the 9–10 years age group. The eruption showed an increase to 52.0% in the 10–11 years age group, with almost complete eruption observed in the 11–12 years age group, thus indicating the critical period to be between 10 and 11 years. The eruption of the maxillary canine teeth showed a delay in comparison to the eruption of the mandibular canine teeth. The eruption of left maxillary canine was observed in only 6.0% of girls at 10–11 years, with almost complete eruption observed, 88.7%, by 12–13 years. The eruption of the right maxillary canine tooth showed the last to have erupted in all quadrants, with no eruption observed in the 9–10 years age group, with only 35.3% showing eruption by the end of 12 years, thus indicating the eruption to have occurred beyond the study period. The sequence in which the canine teeth erupted is thus right mandibular, left mandibular, left maxillary, and finally the right maxillary. These findings highlight the importance of quadrant-specific evaluation rather than reliance on generalized eruption timelines. The timing of the eruption observed in this study differs from the previous studies that have suggested that the eruption of the mandibular canine occurs between 9 to 10 years of age. (10,11). This variation highlights the population-specific nature of dental eruption patterns. This may be due to the population-specific characteristics of the eruption of teeth. An earlier study done in Delhi observed that the eruption of the canine on the right side of the maxilla occurred before the canine on the left side of the maxilla, unlike the observations of this study (11). An earlier study done within a similar geographic setting observed that the eruption of the canine occurred at the age of 11 to 12 years, which is similar to the observations of this study (12). Females tend to have their permanent teeth erupt earlier than males in different populations. This difference in eruption time in females is said to be due to an earlier pubertal growth spurt (13).

Morphological Changes in Erupting Canine Teeth: The morphological changes in erupting canines were examined. The results show that canines in all quadrants had a typical conical shape

shortly after eruption. However, in 11 to 12-year age group, a change in shape to a parabolic form resembling an incisor was seen. This was most pronounced in the right lower quadrant, where 65.3% had an incisor-like shape. In 12 to 13-year age group, a square-cut premolar-like shape was most common. In 50.7% of canines in the left lower quadrant, 39.3% in the left upper quadrant, and 26.0% in the right lower quadrant, canines had a square-cut shape. This morphological flattening of the apex of canines is due to functional loading. Once in occlusion, they are subjected to forces during mastication and interproximal attrition at contact points. The morphological changes in canines - from conical to parabolic to square-cut - can be used as an aid in age estimation when prevalence data cannot discriminate between two age groups.

Odontometric Characteristics: The odontometric values show an increasing trend in both mesiodistal and cervico-incisal values with increasing age in all quadrants where values were obtainable. In erupting teeth, the clinical crown is in part subgingival, with the mesiodistal diameter initially larger than the cervico-incisal height. However, with increasing age in erupting teeth, the cervico-incisal height increased significantly and approached or exceeded the mesiodistal diameter by 12–13 years in the right lower quadrant. The similarity of these dimensions at 12–13 years can be considered an additional parameter to define an advanced stage of eruption and to mark the shift to the adult dental pattern based on the increase in crown height.

Intercanine Distance and its Forensic Relevance: The intercanine distance was found to be greater in the maxilla than in the mandible in all age groups. Among 12 to 13 year-olds, the intercanine distance in the upper jaw was 3.22 ± 0.21 mm, whereas in the lower jaw it was 2.65 ± 0.83 mm. The difference between the maxilla and mandible was approximately 0.5 to 0.8 cm. This difference can be used in forensic odontology to distinguish between bite marks caused by an upper jaw and those caused by a lower jaw. The findings provided in this study are applicable to South Indian schoolgirls in the 12 to 13 year age group.

Limitations: The cross-sectional design does not permit determination of the precise chronological moment of canine emergence for individual participants; the study provides prevalence of eruption at a given time point rather than longitudinal incidence data. Gingival emergence was used as the criterion for eruption, which, while clinically practical and non-invasive, may introduce minor inter-examiner variability. The study population was confined to a single district of Kerala

and may not fully represent all South Indian populations or girls from other geographic, socioeconomic, or ethnic backgrounds. The absence of radiographic staging data limits the ability to correlate clinical eruption status with underlying developmental stages.

CONCLUSION

This study documents the eruption sequence, morphological progression, and odontometric characteristics of permanent canines in South Indian schoolgirls aged 9–13 years from Kozhikode, Kerala. The consistent quadrant-specific eruption sequence - right mandibular, left mandibular, left maxillary, right maxillary - with near-complete mandibular canine eruption by 11–12 years, provides a clinically applicable, sex-specific reference framework for forensic age estimation in this demographic. The age-related morphological transition from typical canine to premolar-like form, and the consistent upper jaw-to-lower jaw differential in intercanine distance, provide additional forensic parameters applicable to bite mark analysis and jaw identification. Together, these findings establish a sex-specific, population-specific, quadrant-wise reference dataset that advances the precision of medico-legal age estimation in South Indian schoolgirls.

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