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Evaluation of Mesiodistal Root Angulation of Permanent Incisors, Canines, and First Pre-Molars by Orthopantomogram Dental Imaging Findings in 296 Children Aged 6-14 Years

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Background: Early pre-eruptive inclination changes of the first premolar (FP) and its associative changes with canine (C) inclination are important to predict canine impaction. This study aimed to evaluate the mesiodistal root angulation of permanent lateral incisors (LI), canines, and first molars by orthopantomogram dental imaging in 296 children ages 6-14 years at a single center in India.

Material/Methods: The total number of participants was 296, with equal numbers of boys and girls divided into 4 age groups: 6-8 years, 8-10 years, 10-12 years, and 12-14 years. Angles between lateral incisor, erupting canine, and first pre-premolar with midline were measured on an orthopantomogram (dental imaging which includes all the teeth with TMJ). The angle between the erupting C with LI and erupting C with FP was measured. Pearson's correlation was also evaluated between the movement of the erupting canine with lateral incisor and erupting canine with erupting first premolar.

Results: There was a significant difference in the angular values of different age groups ($P \leq 0.05$). The movements between LI, C, and FP were moderately correlated boys and girls aged 6-12 years.

Conclusions: The findings from this study showed that in boys and girls aged 6-14 years, eruption of the upper canine tooth was synchronized with eruption of the LI and FP.

Keywords: Dentition, Mixed • Radiography, Dental, Digital • Tooth Eruption

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Background

The canine (C) in the maxillary arch is often found to be impacted after the third molar. The prevalence of maxillary canine impaction is 1.7% in the general population [1]. The causes of this high prevalence of impaction are its extended development period and the long tortuous path it travels before it erupts in the oral cavity [2]. Females show a strong prevalence over males for maxillary canine impactions [3]. Managing C impaction in the maxillary arch is a perplexing problem in routine clinical practice of orthodontics. The pattern of dental eruption can be affected by factors like malnutrition and hormones. It can be studied by either radiographically or clinically in relation to the timing and sequence of eruption. Orthopantomography is used to study the eruptive patterns of C with LI and FP in different age groups. The beginning of calcification of the C crown is 4-12 months and is completed at about 6-7 years. The C is high over the deciduous C at age 8 and then becomes inclined in mesial and occlusal directions until the level of the distal surface of the root of the LI. The erupting maxillary C is progressively moves to a more erect position, which is guided by the distal surface of the root of LI, until it erupts in the oral cavity at age 10-12 years for girls and 11-13 years for boys [4].

The incidence of C impaction in the maxillary arch was 85% on the palatal side and only 15% on the buccal side [5]; 8% of individuals are found to have bilateral maxillary C impactions [6]. The local causes of palatally impacted maxillary C are the inborn absence of LI/FP or anomalies of LI [5]. Incisor root resorption is commonly seen with maxillary impacted teeth, which do not cause any symptoms and is frequently identified late following severe resorption [7]. It is of utmost importance for a clinician to differentiate among the normal angulation of the maxillary permanent LI, C [8], and FP with an abnormal inclination leading to pathological eruption of the C. This needs an in-depth understanding of the normal eruptive pattern of maxillary permanent C. Interceptive management of maxillary C impaction includes extraction of deciduous C, combined with creating space in the maxillary arch by distalization [9] or removal of a deciduous maxillary FP or expanding the dental arch [10]. When interceptive treatment fails, surgical intervention of the maxillary impacted permanent C is needed, requiring orthodontic interventions to bring the canine into the oral cavity [11]. As the patient grows older, the length and difficulty of treatment also increase [12].

Interceptive treatment with removal of both maxillary deciduous C and deciduous first molar is found to be more beneficial than removal of only maxillary deciduous C [13,14]. These double extractions lead to a significant change in inclination of the FP, which in turn uprights the C, conforms to the association of that change in the FP inclination, will affect the inclination of the C, and will prevent impactions [15]. Therefore, early pre-eruptive inclination changes of the FP and its associative changes with C inclination is also an important factor to predict the fate of maxillary C, but to date, there is only 1 retrospective study [16] that has tried to correlate eruption pattern of maxillary FP with the erupting C, and the study evaluated the inclination of the FP, C, and LI at 8 years and 10 years only. Hence, there is a need to evaluate the early pre-eruptive inclination changes and their association with canine inclinations till the C erupts in the oral cavity. Cone-beam computed tomography may not be the first choice in assessing the position and eruption pattern of teeth in terms of cost and biology [17,18]. Therefore, the present study aimed to evaluate the mesiodistal root angulation of permanent incisors, canine, and first premolar by orthopantomogram dental imaging in 296 children aged 6-14 years at a single center in India.

Hypothesis

We hypothesized that here is an association of pre-eruptive inclination changes of maxillary FP with inclination changes of maxillary C. This leads to the hypothesis that any abnormal pre-eruptive inclination of the maxillary FP will lead to eruptive problems of the maxillary C. Hence, the study is planned to assess the mesiodistal inclinations of the maxillary permanent C, LI, and the FP in children aged 6-14 years.

Aim

The aim of the study was to evaluate normal mesiodistal root angulation of permanent incisors, canines, and first molars in 296 boys and girls aged 6-14 years at a single center in India using orthopantomography.

Material and Methods

The study obtained ethics approval from Sumandeep Vidyapeeth Institutional Ethics Committee (SVIEC/ON/Dent/Ph.D./16002.). Written informed consent was obtained from the participants and their parents to participate in the study. The participants were 6-14 years of age and had maxillary deciduous C and maxillary first permanent molar in place. The total number of participants was 296. The participants were selected in such a manner that each group consisted of an equal number of boys (148) and girls (148). There were 37 participants aged 6-8 years, 37 aged 8-10 years, 37 aged 10-12 years, and 37 aged 12-14 years in both boys and girls. The sample size was calculated according to the study by Giulio Alessandri Bonetti [8]. A total of 250 participants were needed to achieve the power of 80 to determine the effect size of 0.2000 using 20 degrees of freedom, with the chi-square test with a level of significance (alpha) of 0.05.

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All the participants who were included in the study came in for a routine dental examination. A clinical examination was performed and orthopantomography was performed as radiographic examination. Orthopantomographs of all these participants were collected for the study after obtaining written consent from the participants and their parents after explaining the details of the study. The radiographic method of evaluation of eruption pattern used orthopantomography (Carestream Dental OPG CS8100, 8 to 12 mA, 55 to 85kVp). Any patients with signs of early predictors of probable impaction [19] of C in the future in the clinical and radiographic examination were excluded. We also excluded patients with previous orthodontic treatment, history of traumatic injury, agenesis of any tooth, odontomas, cysts, supernumerary teeth, small or peg-shaped LI, any abnormality of the FP, cleft lip and palate, any craniofacial syndromes, ankylosis of deciduous canine, premature exfoliation of deciduous canine with drifting of adjacent teeth, or loss of space of permanent C before its eruption.

All orthopantomographs were digitized in Dolphin cephalometric software (11.9) and the following parameters were analyzed.

Lateral incisor inclination: The angle formed between midline constructed according to Power and Short21and the vertical axis of the maxillary LI (**Figure 1**).

Canine inclination: The angle formed by the vertical axis of erupting maxillary permanent C to midline [20] (**Figure 2**).

Premolar inclination: The angle formed by the vertical axis of erupting maxillary FP to midline [15] (**Figure 3**).

The angle formed by C and LI: The angle formed by the vertical axis of erupting maxillary permanent C and the vertical axis of permanent LI [21] (**Figure 4**).

The angle between C and FP: The angle formed by the vertical axis of erupting maxillary permanent C and the vertical axis of the FP (**Figure 5**).

Mesio distal position of C and FP: The location of erupting maxillary permanent C cusp tip and erupting maxillary FP cusp tip were evaluated according to sector classification [22] (**Figure 6**).

Sector 0: Space distal to the crown and root of the deciduous C.
Sector 1: Area between distal surface and the long axis of deciduous C.
Sector 2: Space between the long axis of the deciduous C and the distal surface of the LI.
Sector 3: Area between distal surface and the vertical axis of the maxillary permanent LI.
Sector 4: Space between the long axis and the mesial surface of the LI.
Sector 5: Area between the mesial surface of the LI to the long axis of the maxillary permanent central incisor.
Sector 6: Area between the long axis of maxillary permanent central incisor to the midline.

Statistical Analysis

The means of the inclination of the LI, C, and FP with the midline were calculated in all groups. We also calculated the means of angular values between C and LI, C, and FP. Significant differences between the inclinations of LI with the midline in all the groups, the inclination of canine with the midline in all the groups, and inclination of FP with the midline in all the groups were evaluated with the ANOVA test. Significant differences between the angle by the long axis of maxillary erupting C and permanent LI in all groups, long axis of erupting maxillary C, and erupting the FP in all the groups were evaluated by ANOVA test. Pearson's correlation was evaluated between the angles of LI with midline and C with the midline in all the groups. Similarly, Pearson correlation was evaluated between the angles of C with midline and FP with the midline in all the groups. Pearson's correlation was evaluated between the angle formed by C with LI and C with the FP in all the groups. All these were evaluated in boys and girls. All the parameters were evaluated twice with an interval of 3 weeks by the same trained investigator for evaluating the intra-class correlation coefficient.

Results

We obtained 296 orthopantomographs from children aged 6-14 years. There were 148 boys and 148 girls. Thirty-seven boys were aged 6-8 years, 37 boys were aged 8-10 years, 37 were aged 10-12 years, and 37 were aged 12-14 years. Similarly, 37 girls were aged 6-8 years, 37 girls were aged 8-10 years, 37 were aged 10-12 years, and 37 were aged 1-14 years.

All the measurements were recorded twice with an interval of 3 weeks with the same trained examiner. The intra-class correlation coefficient between the 2 measurements was 0.97. There was no difference between right- and left-side measurements. For analysis, only 1 side value was considered.

There was a statistically significant difference in mean ages of 4 groups in boys (P=0.032) as well as in girls (P=0.026) (**Table 1**).

The mean angulations of LI with midline in boys were 2.2±0.19° in those aged 6-8 years, 17.1±2.07° in those 8-10 years old, 7.9±0.98° in those 10-12 years old, and 4.2±0.85° in those 12-14 years old, and the differences were statistically significant (P=0.021). Similarly, the C, with midline was 4±0.42° in those 6-8 years, 12.3±1.9^0 in those 8-10 years, 5.4±0.37° in those 10-12 years, and 3.2±0.76° in those 12-14 years, and

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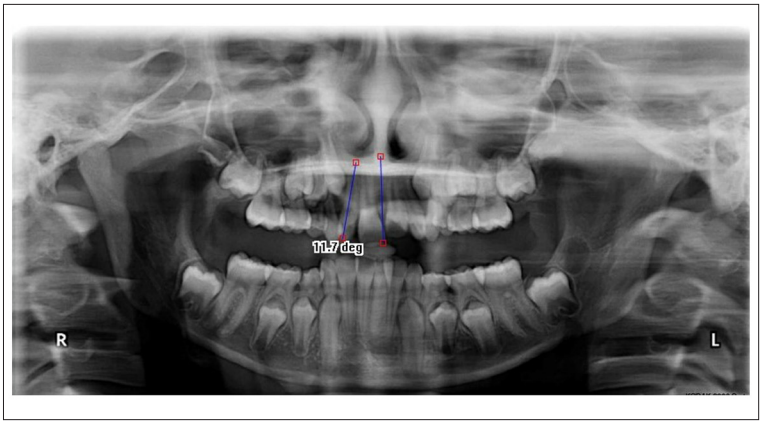

Figure 1. Angle formed by long axis of lateral incisor (LI) and midline between the central incisors on orthopantomograph.

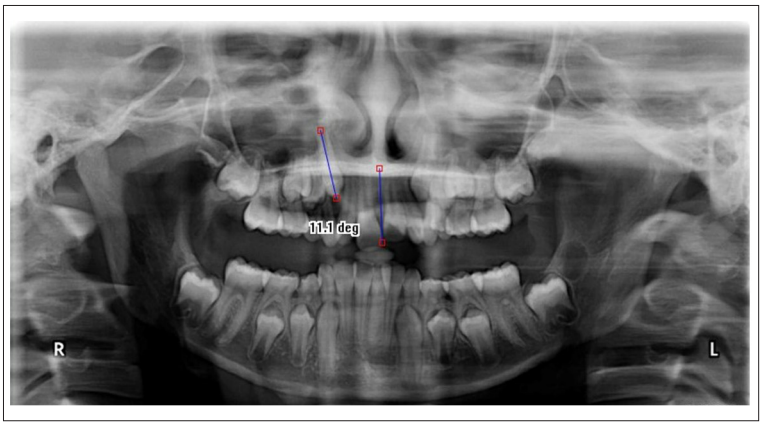

Figure 2. Angle formed by the long axis of canine (C) and midline between the central incisor on orthopantomograph.

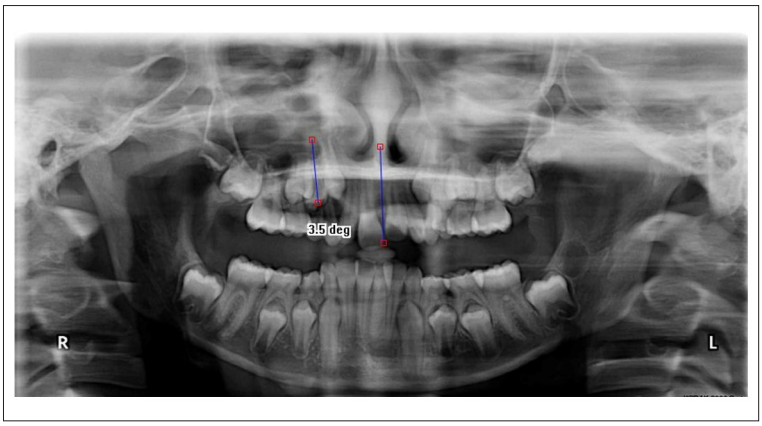

Figure 3. Angle formed by the long axis of first premolar (FP) and midline between the central incisor on orthopantomograph.

the differences were statistically significant (*P*=0.028). The FP with midline angulation values were 3.2±0.96° in those 6-8 years, 11.7±1.58° in those 8-10 years, 5.1±1.04° in those 10-12 years, and 2.9±0.42° in those 12-14 years, and the differences were statistically significant (*P*=0.032) (**Table 2**).

The mean angulations of LI with midline in girls were 2±0.42° in those 6-8 years, 15.3±1.8° in those 8-10 years, 5.3±1.8° in those 10-12 years, and 2.2±0.3° in those 12-14 years, and the differences were statistically significant (*P*=0.021). Similarly, the angulations of C with midline were 4.2±1.03° in those 6-8 years, 12±2.56° in those 8-10 years, 3.4±0.87° in those 10-2 years, and 1.4±0.87° in those 12-14 years, and the differences were statistically significant (*P*=0.032). The FP with midline angulation values were 2.9±0.64° in those 6-8 years, 11.8±1.32° in those 8-10 years, 4.8±0.92° in those 10-12 years, and 2.7±0.32° in those 12-14 years, and the differences were statistically significant (*P*=0.023) (**Table 2**).

The mean angulations of LI with C in boys were 5±1.17° in those 6-8 years, 25.9±4.09° in those 8-10 years, 10.7±2.12° in those 10-12 years, and 4.2±0.4° in those 12-14 years, and the

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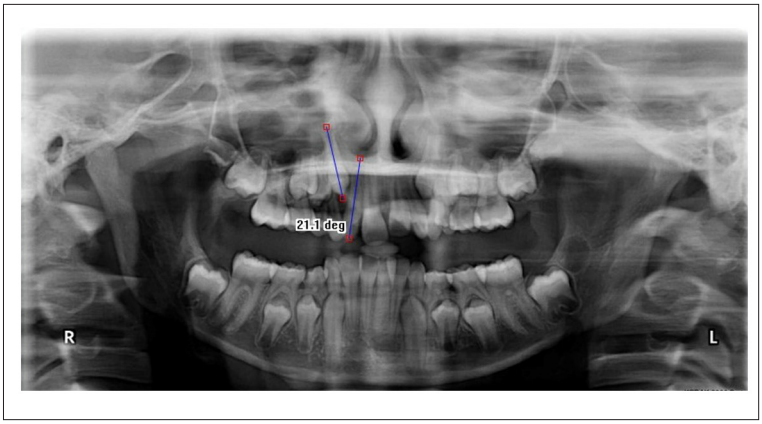

Figure 4. Angle formed by the long axis of (C) with long axis of (LI) on orthopantomograph.

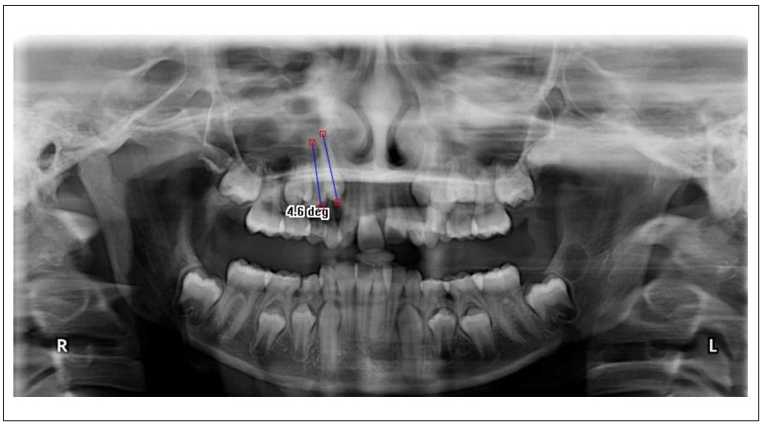

Figure 5. Angle formed by long axis of (C) and long axis of (FP) on orthopantomograph.

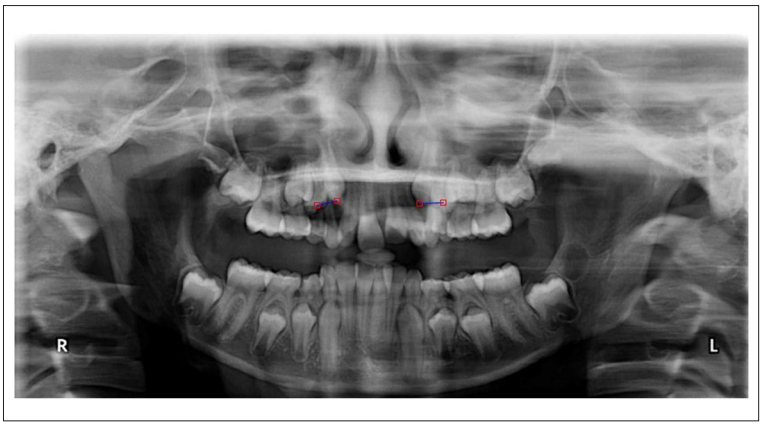

Figure 6. The position of cusp tips of (C) and (FP) on orthopantomograph.

differences were statistically significant (*P*=0.28). The mean angulation of FP with C was 2.1±0.51° in those 6-8 years, 2.3±1.02° in those 8-10 years, 3.1±1.56° in those 10-12 years, and 0.7±0.13° in those 12-14 years, and the differences were statistically significant (*P*=0.034).

The mean angulations of LI with C in girls were 6.3±2.11° in those aged 6-8 years, 19.4±3.53° in those 8-10 years, 8.3±1.05° in those 10-12 years, and 2.4±0.4° in those 12-14 years, and the differences were statistically significant (*P*=0.29). The mean angulations of the first premolar with C were 2±0.23° in those 6-8 years, 2.2±0.12° in those 8-10 years, 3.4±0.87° in those 10-12 years, and 1.4±0.28° in those 12-14 years, and the differences were statistically significant (*P*=0.027).

The movement of maxillary permanent LI to the midline angulations and C with midline angulations was moderately correlated and highly significant for all the age groups in boys and girls, except in the age group of 12-14 years. Movement of the FP to the midline angulations and C to midline angulations was also moderately correlated and highly significant in both boys and girls, except in the age group 12-14 years (**Table 3**).

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Table 1. Mean age of various groups in boys and girls with a statistical significance of *P*=0.05 by ANOVA.

Groups	6-8 years	8-10 years	10-12 years	12-14 years	P-value
Boys (mean age)	7.018	9.043	11.097	13.078	0.023
Girls (mean age)	7.024	9.016	11.097	13.1	0.026

Statistical significant P=0.05.

Table 2. Mean angle of the long axis of the maxillary permanent lateral incisor (LI), maxillary erupting canine (C), and maxillary erupting first premolar (FP) with midline with a statistical significance of *P*=0.05 by ANOVA in boys and girls.

	Angle with midline	6-8 years	8-10 years	10-12 years	12-14 years	P-value
Boys	Lateral Incisor	-2.2±0.19	-17.1±2.07	-7.9±0.98	-4.2±0.85	0.021
	Canine	4±0.42	12.3±1.9	5.4±0.37	3.2±0.76	0.028
	First Premolar	3.2±0.96	11.7±1.58	5.1±1.04	2.9±0.42	0.032
Girls	Lateral Incisor	-2±0.42	-15.3±1.8	-5.3±1.03	-2.2±0.3	0.021
	Canine	4.2±1.03	12±2.56	3.4±0.87	1.4±0.87	0.032
	First Premolar	2.9±0.64	11.8±1.32	4.8±0.92	2.7±0.32	0.023

Statistical significant P=0.05.

Table 3. Pearson's correlation between angles of LI with midline and C with midline with statistical significance of *P*=0.05 by unpaired *t* test in boys and girls.

Age groups	Angulation with midline	Pearson correlation	P-value
6 to 8 years Boys	Lateral incisor with canine	0.54	0.031
	Canine with the first premolar	0.56	0.022
6 to 8 years Girls	Lateral incisor with canine	0.59	0.022
	Canine with the first premolar	0.57	0.023
8 to 10 years Boys	Lateral incisor with canine	0.51	0.031
	Canine with the first premolar	0.54	0.016
8 to 10 years Girls	Lateral incisor with canine	0.49	0.025
	Canine with the first premolar	0.54	0.017
10 to 12 years Boys	Lateral incisor with canine	0.57	0.021
	Canine with the first premolar	0.47	0.021
10 to 12 years Girls	Lateral incisor with canine	0.51	0.018
	Canine with the first premolar	0.44	0.021
12 to 14 years Boys	Lateral incisor with canine	0.10	0.45
	Canine with the first premolar	0.14	0.63
12 to 14 years Girls	Lateral incisor with canine	0.23	0.76
	Canine with the first premolar	0.13	0.77

Statistical significant P=0.05.

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Table 4. Pearson's correlation between the angulations of LI with C and C with the FP with statistical significance of *P*=0.05 with unpaired *t* test.

Age groups	Angulations	Pearson correlation	P-value
6 to 8 years Boys	Lateral incisor – canine with canine – first premolar	0.57	0.02
6 to 8 years Girls	Lateral incisor – canine with canine – first premolar	0.59	0.026
8 to 10 years Boys	Lateral incisor - canine with canine - first premolar	0.55	0.024
8 to 10 years Girls	Lateral incisor – canine with canine – first premolar	0.57	0.028
10 to 12 years Boys	Lateral incisor – canine with canine – first premolar	0.21	0.54
10 to 12 years Girls	Lateral incisor – canine with canine – first premolar	0.18	0.67
12 to 14 years Boys	Lateral incisor – canine with canine – first premolar	0.12	0.73
12 to 14 years Girls	Lateral incisor – canine with canine – first premolar	0.16	0.77

Statistical significant P=0.05.

Table 5. The cusp tips of (C) and (FP) in all age groups of boys and girls.

Age	Cusp tips	Sector
6 to 8 years Boys	Canine	2
	First premolar	0
6 to 8-year-old Girls	Canine	2
	First premolar	0
8 to 10-year-old Boys	Canine	2
	First premolar	0
8 to 10-year-old Girls	Canine	2
	First premolar	0
10 to 12 years old Boys	Canine	2 or 1
	First premolar	0
10 to 12 years old Girls	Canine	2 or 1
	First premolar	0
12 to 14 years old Boys	Canine	1
	First premolar	0
12 to 14 years old Girls	Canine	1
	First premolar	0

Statistical significant P=0.05.

Angulations of C and LI with angulations of C and FP were moderately correlated and highly significant in boys aged 6-8 years and in girls aged 8-10 years, but the correlations were weak and were not significant in boys 11-12 years and in girls 12-14 (**Table 4**).

The cusp tip of the erupting canine is in sector 2 in boys aged 6-8 years and in girls 8-10 years of age. In both boys and girls aged 10-12 years, the cusp tip of the erupting canine slowly shifts from sector 2 to sector 1. The erupting cusp tip of the first premolar was always in sector 0 in all groups of boys and girls (**Table 5**).

Discussion

The ideal design for this type of study is longitudinal, following the sample participants from age 6 years to 12 years, taking serial panoramic radiographs. In such a longitudinal study, the attrition rate of the sample might be high and ethics may not permit exposing children to X-rays for the study. Many studies have reported a relationship between the movement of the C and LI when the C is erupting [8,23-25]. However, no previous study has given the angular values of erupting C with midline and canine with LI, and C with FP in various age groups until the C erupts in the oral cavity. Hence, we are planning a cross-sectional study on orthopantomography collected from those individuals who came in for a routine dental examination.

The present study evaluated the angular values of LI, C, and FP with midline in children aged 6-8 years, 8-10 years, 10-12 years, and 12-14 years, with a statistically significant difference between the age groups in both boys and girls. The mean angulation between C and LI in all the age groups and between C and FP in all the age groups were statistically significantly different in both boys and girls.

Most studies [8,15,25,26] that evaluated the eruptive movement of canine, first premolar, and lateral incisor were retrospective, and no study has evaluated the normal pre-eruptive angulations of the C, LI, and FP in children aged 6-12 years. In the present study, orthopantomography [15] was used, which is a two-dimensional image of a three-dimensional object.

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Table 6. Mean angulations of LI with C and FP with canine with a statistical significance of *P*=0.05 with ANOVA in boys and girls.

	Angle	6-8 years	8-10 years	10-12 years	12-14 years	P-value
Boys	Lateral incisor and canine	5±1.17	25.9±4.09	10.7±2.12	4.2±0.4	0.028
	First premolar and canine	2.1±0.51	2.3±1.02	3.1±1.56	0.7±0.13	0.034
Girls	Lateral incisor and canine	6.3±2.11	19.4±3.53	8.3±1.05	2.4±0.4	0.029
	First premolar and canine	2±0.23	2.2±0.12	3.4±0.87	1.4±0.28	0.027

Statistical significant P=0.05.

Orthopantomographs were used for this study because these diagnostic radiographs are commonly taken for screening purposes, especially in children who come for a routine dental examination. As soon as an erupting canine is shown on orthopantomography it should be predicted whether the canine is erupting normally or abnormally at that particular stage. Moreover, the radiation exposure for orthopantomography is lower than with three-dimensional imaging.

In this study, we evaluated the angulations of the LI, erupting C, and the FP with midline. Also, the angle between LI with C and FP with C was evaluated in boys and girls aged 6-12 years, which is the period of eruption of C from the floor of the nose until it comes out in the oral cavity. Between the ages of 6 to 8 years, the C crown gets calcified and hits the distal surface of the root of the LI, making the root of the LI move mesially and crown distally, creating space between the crowns of the LI and central incisors, which is known as the "ugly duckling" stage. The angular values in this period were represented by negative symbols because C and LI were inclined opposite to each other.

Shin et al [26] also stated that the angle between C and LI in a normal erupting C will first increase and then decrease as the C approaches the cervical area of the LI. This results in the "ugly duckling" stage and will self-correct after the C has fully erupted into the oral cavity. These angular values between the LI and impacted C do not follow any pattern and remarkably deviate from normal angular values between erupting C and the LI (**Table 6**). Shin et al also stated that the 3 best parameters which will discriminate from impacted canine with normally erupting C are the angle between erupting C and erupting the FP, C cusp tip-midline linear distance, and C cusp tip-maxillary occlusal plane linear distance, but the predictive ability is weak unless they are used in the regression formula provided in that study.

We found that C has an influence on both LI and FP during its erupting phase. The movements of the lateral incisor and first premolar appear as though they are pre-programmed with the movement of the erupting C. The movement of permanent LI with C and the movement of the erupting FP with C are moderately correlated in children aged 6-8, 8-10, and 10-12 years, and were highly significant in both boys and girls ($P \leq 0.05$), but in the boys and girls aged 12-14 years, this correlation was very weak and was not significant in boys or girls. This might be because the canine at age 12-14 years might have already erupted in the oral cavity and may not affect the LI and FP.

Bonetti has stated that removal of both deciduous maxillary C and deciduous first molar will spontaneously upright the erupting FP, which in turn will influence uprighting the erupting C, which can prevent impaction of C [15]. This is in agreement with our study, which shows that canine and premolar movements are correlated with each other during their eruption.

In our study, the mean normal angulation of LI with the midline in boys 6-8 years old was about -2.2°, which will increase to -17° in boys aged 8-10 years and then decreases to -7.9° at age 10-12 years, and at age 12-14 years it becomes upright with angulation of -4.2°. In girls, the mean normal angulation at age 6-8 years is -2, which will increase to -15° at 8-10 years and will decrease to -5° at 10-12 years, which will almost upright to -2.2° in 12 to 14 years. The angulations of the LI to the midline are presented with a negative symbol because the movement of the LI is opposite to that of the erupting C and FP. A similar pattern of angular values is followed in erupting C and FP with midline, which is presented in **Table 6**. The mean angulation between LI and C in boys at the age of 6 to 8 years is 5°, which will increase to 25° at the age of 8-10 and will again decrease to 10° at the age of 10-12 years, and both the teeth will become almost entirely upright at the age of 12-14 years, with an angle of 4.2°. In girls, the mean angulation is 6.3° at the age of 6-8 years, which will increase to 19.4° at the age of 8-10 years and will again decrease to 8.3° at the age of 10-12 years, and both teeth will become almost completely upright with 2.4° by the age of 12-14 year. In contrast, the angulation between the erupting C and FP is about 2° at age 6-8 years and will increase to only 3° at 10-12 years and 0.7 at age 12-14 years. The movement of C and FP will be almost parallel to each other during their eruption in both boys and girls aged 6-12 years (**Table 6**).

The cusp tip of the C at the age of 6-10 years will be in the distal long axis of the maxillary permanent LI and the mesial long axis of the deciduous C (Sector 2). This cusp tip shifts in the distal direction and will be between the mesial aspect of the

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deciduous C and its long axis at the age of 10-12 years (Sector 1) and will be in line with the long axis of the deciduous C at the age of 12-14 years in both boys and girls. The erupting first premolar cusp tip is always distal to the distal long axis of the deciduous C (Sector 0) until it erupts in the oral cavity.

Study Limitations

The drawback of this study is its cross-sectional design, as ethics committee approval might not be given for a longitudinal design that requires exposure of children to radiography. The other reason to choose a cross-sectional design is the attrition of the sample, as it may take a prolonged period for a longitudinal study to follow the same subjects from age 6 to 14 years. However, the ideal design for this type of study is a longitudinal study. A longitudinal study with a larger sample may provide more accurate results.

Conclusions

The findings from this study showed that in both boys and girls aged 6-14 years, eruption of the upper canine tooth was synchronized with the lateral incisor and first premolar.

The normal pre-eruptive angles of lateral incisor, canine and first premolar with the midline were evaluated at ages 6-8, 8-10, 10-12, and 12-14 years in boys and girls. The angulations between canine with lateral incisor and canine with the first premolar were also evaluated at ages 6-8, 8-10, 10-12, and 12-14 in boys and girls. There was a moderate correlation between the movement of the canine on the lateral incisor and the first premolar at 6-12 years of age. These normal angular values help the clinician to differentiate a normally erupting canine from an abnormally erupting canine that will become impacted in the future. By identifying an abnormally erupting canine at an early age, the preventive and interceptive treatment procedures will help in preventing future canine impaction.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

References:

1. Kurol J. Early treatment of tooth-eruption disturbances. Am J Orthod Dentofac Orthop 2002;121:588-91
2. Andreasen JO, Petersen JK, Laskin DM. Textbook and colour atlas of tooth impactions: diagnosis, treatment, prevention. Copenhagen, Denmark: Munskgaard. 1997;126
3. Bishara SE, Ortho. D. Impacted maxillary canines: A review. Am J Orthod Dentofac Orthop. 1992;101:159-71
4. van der Linden FPG. Transition of the human dentition. Monogr 13 Craniofacial Growth Ser Ann ArborCenter Hum Growth Dev Univ Michigan. 1982;102-5
5. Ericson S, Kurol J. Radiographic examination of ectopically erupting maxillary canines. Am J Orthod Dentofac Orthop. 1987;91:483-92
6. Peck S, Peck L, Kataja M. Site-specificity of tooth agenesis in subjects with maxillary canine malpositions. Angle Orthod. 1996;66:473-76
7. Rimes RJ, Mitchell CNT, Willmot DR. Maxillary incisor root resorption in relation to the ectopic canine: A review of 26 patients. Eur J Orthod. 1997;19:79-84
8. Alessandri Bonetti G, Incerti Parenti S, De Rinaldis S, Marini I. Association between the inclination of the lateral incisors and the position of the erupting canines on panoramic radiographs. Acta Odontol Scand. 2011;69:222-28
9. Baccetti T, Leonardi M, Armi P. A randomized clinical study of two interceptive approaches to palatally displaced canines. Eur J Orthod. 2008;30:381-85
10. Baccetti T, Sigler LM, McNamara JA. An RCT on treatment of palatally displaced canines with RME and/or a transpalatal arch. Eur J Orthod. 2011;33:601-7
11. Caminiti MF, Sandor GK, Giambattistini C, Tompson B. Outcomes of the surgical exposure, bonding and eruption of 82 impacted maxillary canines. J Can Dent Assoc. 1998;64:572-74, 576-79
12. Becker A, Chaushu S. Success rate and duration of orthodontic treatment for adult patients with palatally impacted maxillary canines. Am J Orthod Dentofac Orthop. 2003;124:509-14
13. Caprioglio A, Vanni A, Bolamperti L. Long-term periodontal response to orthodontic treatment of palatally impacted maxillary canines. Eur J Orthod. 2013;35:323-28
14. Alessandri Bonetti G, Incerti Parenti S, Daprile G, Montevecchi M. Failure after closed traction of an unerupted maxillary permanent canine: Diagnosis and treatment planning. Am J Orthod Dentofac Orthop. 2011;140:121-25
15. Alessandri Bonetti G, Incerti Parenti S, Zanarini M, Marini I. Double vs single primary teeth extraction approach as prevention of permanent maxillary canines ectopic eruption. Pediatr Dent. 2010;32(5):407-12
16. Incerti Parenti S, Marini I, Ippolito DR, Alessandri Bonetti G. Preeruptive changes in maxillary canine and first premolar inclinations: A retrospective study on panoramic radiographs. Am J Orthod Dentofac Orthop. 2014;146:460-66
17. Liu D, Zhang W, Zhang Z, et al. Localization of impacted maxillary canines and observation of adjacent incisor resorption with cone-beam computed tomography. Oral Surgery Oral Med Oral Pathol Oral Radiol Endodontology. 2008;105:91-98
18. Maverna R, Gracco A. Different diagnostic tools for the localization of impacted maxillary canines: clinical considerations. Prog Orthod. 2007;8:28-44
19. Alqerban A, Jacobs R, Fieuws S, Willems G. Radiographic predictors for maxillary canine impaction. Am J Orthod Dentofac Orthop. 2015;147:345-54
20. Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. Eur J Orthod. 1988;10:283-95
21. Alessandri Bonetti G, Zanarini M, Incerti Parenti S, et al. Preventive treatment of ectopically erupting maxillary permanent canines by extraction of deciduous canines and first molars: A randomized clinical trial. Am J Orthod Dentofac Orthop. 2011;139:316-23
22. Alessandri Bonetti G, Zanarini M, Danesi M, et al. Percentiles relative to maxillary permanent canine inclination by age: A radiologic study. Am J Orthod Dentofac Orthop. 2009;136:486.e1-.e6
23. Stramotas S, Geenty JP, Darendeliler MA, et al. The reliability of crown-root ratio, linear and angular measurements on panoramic radiographs. Clin Orthod Res. 2000;3:182-91
24. Lindauer SJ, Rubenstein LK, Hang WM, et al. Canine impaction identified early with panoramic radiographs. J Am Dent Assoc. 1992;123:91-97
25. Warford JH, Grandhi RK, Tira DE. Prediction of maxillary canine impaction using sectors and angular measurement. Am J Orthod Dentofac Orthop. 2003;124:651-55
26. Shin JH, Oh S, Kim H, et al. Prediction of maxillary canine impaction using eruption pathway and angular measurement on panoramic radiographs. Angle Orthod. 2022;92:18-26

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