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ORIGINAL ARTICLE

Association between the inclination of the lateral incisors and the position of the erupting canines on panoramic radiographs

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Abstract

Objective. To analyze correlations between the inclination of the permanent maxillary lateral incisors and the intraosseous position of the erupting permanent maxillary canines on panoramic radiographs. ***Material and methods.*** The inclination of the lateral incisor to the midline, the mesiodistal position of the crown of the canine, and the inclination of the canine to the midline and to the long axis of the adjacent incisor were measured on panoramic radiographs of 1013 subjects aged 8–11 years. ***Results.*** The distal inclination of the lateral incisor crown increased until 10 years, after which no significant changes occurred. The canine erupted with increasing mesial inclination of the crown until 9 years, after which it began to progressively right itself. As a result, inclination of the canine to the adjacent incisor increased between 8 and 9 years and decreased between 10 and 11 years. Until the children reached 9 years of age, the more mesial the crown of the unerupted canine, the greater the decrease in the distal inclination of the lateral incisor crown. ***Conclusions.*** The inclination of the crown of the lateral incisor varies during eruption of the canine, increasing distally until 10 years as a physiological stage in the mixed dentition. The inclination of the lateral incisor is also associated with the mesiodistal position of the canine crown. The mesial intraosseous location of the canine crown results in righting of the lateral incisor.

Key Words: *Canine, early detection, lateral incisor, mixed dentition, panoramic radiographs*

Introduction

Orthodontists, pediatric dentists, and general practitioners must be prepared for early interception of ectopic eruption of the permanent maxillary canines by the age of 8 years [1–5] and for prevention of impaction by deciduous extraction [6–8]. This reduces the incidence of resorbed incisor roots, decreases the patient's need for oral surgery, and simplifies orthodontic treatment [5–14]. Predictive signs of eruptive disorders of the canines on panoramic radiographs are excessive mesial inclination of their crown to the midline [8,15] or an overlapping between the cusp and the root of the adjacent permanent maxillary lateral incisor [7,14,15]. Moreover, excessive distal inclination of the lateral incisor crown has been related to mesially deflected canines, which have the potential to become impacted [3,4,16–18]. However, it is still controversial whether the inclination of the lateral incisors also varies in the course of normal eruption of the canines.

There are few studies, most with conflicting outcomes, that describe the change in inclination of lateral incisors during mixed dentition [19,20] while specifically focusing on its relation to the intraosseous position of the erupting canines [21]. Broadbent [19] concluded that the crown of the incisor may temporarily tip distally between 8 and 10 years of age, when the crown of the erupting canine is in close contact with the distal aspect of the apical end of the root of the incisor (the 'ugly duckling' stage), while Tsai [20] found no variation in the inclination of the lateral incisor during eruption of the canine. An inclination of the canine exceeding 28° to the adjacent incisor has also been reported as an increased risk factor for root resorption [21]. The ability to distinguish the physiological inclination of the lateral incisor from an inclination indicating a pathological eruption pattern of the canine would be particularly relevant for

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clinicians, and requires an understanding of the normal eruptive pattern. Three-dimensional imaging would be elective in evaluating the position of the incisor in the three planes of space as well as in assessing whether any root resorption has taken place, but the costs (from an economic and, more importantly, a biological point of view) are still prohibitive in many practices [22,23]. Therefore, this study focused on the mesiodistal inclination of the lateral incisor as detected by routine two-dimensional panoramic radiographs in the mixed dentition. The purpose of the study was to analyze correlations between the inclination of the lateral incisor and the intraosseous position of the erupting canine using panoramic radiographs taken from a large sample of children of Caucasian origin from northern Italy between the ages of 8 and 11 years.

Material and methods

An observational, cross-sectional study was carried out using panoramic radiographs of 1013 healthy children from northern Italy. The study protocol was approved by the Institutional Review Board. All of the radiographs were collected between 2000 and 2008 from the Department of Radiology, School of Dentistry, University of Bologna, Bologna, Italy. Inclusion criteria were: (1) Caucasian origin, (2) age 8–11 years, (3) presence of primary maxillary canines in the dental arch, and (4) good-quality radiographs taken for purposes other than orthodontic evaluation or treatment. Exclusion criteria were: (1) previous orthodontic treatment, (2) trauma, (3) agenesis, (4) odontomas, (5) cysts, (6) supernumerary teeth in the study zone, (7) small or peg-shaped lateral incisors, (8) craniofacial syndromes, and (9) cleft lip or palate (or both). Patients referred to the Department of Radiology were included to provide data comparable to those of the general pediatric population aged 8–11 years and to prevent any potential bias by selecting subjects seeking orthodontic treatment because of the referral pattern to a specific specialist unit [9]. The age and sex distributions of the patients are presented in Table I. All panoramic radiographs were taken using the same apparatus (Planmeca ProMax Orthopantomograph; Planmeca Oy, Helsinki, Finland) following a standardized procedure.

Table I. Patient distribution by age and sex.

Age group (years)	No. of males	No. of females	% of subjects[a]	Total no. of subjects
8	147	164	31	311
9	113	125	23	238
10	115	118	23	233
11	127	104	23	231
Total	502	511	100	1013

[a]Percentages were rounded to the nearest whole number.

Measurements

Each radiograph was digitized at 300 dpi and in grayscale mode using a scanner (Epson Expression 1680 Pro; Cinisello Balsamo, Milan, Italy) and a JPEG format was used for disk storage. Because previous studies have already confirmed the reliability of angular measurements in panoramic radiographs [9,24,25], the following angular values were calculated using measurement software (LightningPlant version 1.0.0; ElleSoft, Chieti, Italy) by the same evaluator (S. D. R.):

- Inclination of the lateral incisor (angle α_i): the angle formed by using the midline, constructed according to Power & Short [8], and the long axis of the lateral incisor; distal angle (Figure 1).
- Inclination of the canine (angle α_c) [6]: expressed as the inclination of the long axis of the canine to the midline [8]; mesial angle (Figure 1).
- Inclination of the canine to the adjacent incisor (angle β) [21]: the angle formed by the intersection between the long axis of the canine and the long axis of the lateral incisor; mesial angle (Figure 1).

The mesiodistal position of the cusp tip of the unerupted canine was located in accordance with the sector analysis employed by Leonardi et al. [10] and Baccetti et al. [11], which was taken from Ericson & Kurol [6] (Figure 1). These measurements were made on the lateral incisors and canines on both the maxillary left and right sides of each patient, with a total sample of 2026 lateral incisors and 2026 canines.

Reliability

In order to test intra-observer reliability, panoramic radiographs of 20 randomly selected subjects (five for each age group) were redigitized by the same evaluator (S. D. R.), who measured all of the radiographic variables twice at 2-week intervals. For inter-observer reliability, panoramic radiographs of 20 randomly selected subjects (five for each age group) were redigitized and measured independently by five experienced orthodontists and five students in the dental school. The intra-class correlation coefficients (ICCs) were calculated to assess the intra- and inter-observer agreements.

Statistical analysis

Median and interquartile range, skewness, and kurtosis coefficients were used for descriptive analyses. The distribution was evaluated using the

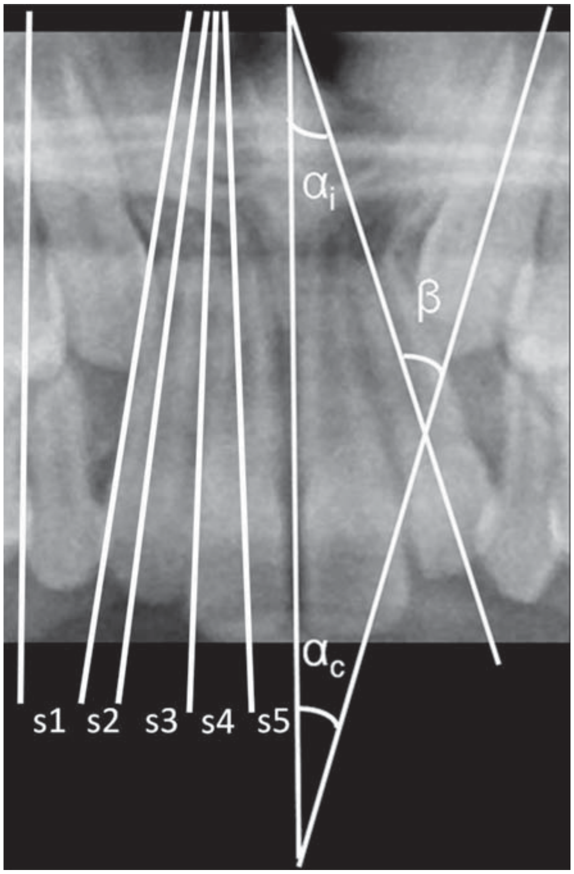

Figure 1. The inclination of the lateral incisor (angle α_i) and the inclination of the canine to the midline (angle α_c) and to the long axis of the adjacent lateral incisor (angle β). The mesiodistal position of the unerupted canine cusp tip is measured by sector (s1–s5).

Kolmogorov–Smirnov test for all angles. The Mann–Whitney test was performed to compare the angular measurements between the sexes, while differences between ages were assessed using the Kruskall–Wallis test. The data on the right and left sides were compared using the Wilcoxon test for paired data across the four age groups. Percentile distributions by age were employed for the angular measurements (Figures 1–3). Contingency tables were used to investigate possible associations between the sector of the canines and age; a Kruskall–Wallis ANOVA was performed to compare the sector of the canines and the angular measurements within each age group, and Pearson's correlation was used to investigate possible associations between the angular measurements. Statistical analyses were performed using the statistical software SPSS for Windows (version 16.0; SPSS Inc., Chicago, IL). P-values < 5% were considered significant.

Results

The data relating to the inclination of the incisors (angle α_i) and of the canines (angle α_c) for either the right or left side were not normally distributed as assessed by the Kolmogorov–Smirnov test (P = 0.028 and P = 0.001; P = 0.036 and P = 0.009, respectively). They presented a positive asymmetry (0.340 ± 0.007 and 0.819 ± 0.07; 0.419 ± 0.077 and 0.721 ± 0.077, respectively) and leptokurtosis (1.776 ± 0.154 and 2.896 ± 0.154; 0.489 ± 0.154 and 1.335 ± 0.154, respectively). The measurements relating to the inclination of the canines to the adjacent incisors (angle β) were consistent with a Gaussian distribution, but because some data subgroups were not normally distributed, non-parametric tests were used to make the descriptions uniform among all of the examined variables.

The results are presented for males/females and right/left sides together because there were no statistically significant differences between the sexes or sides. Since a statistically significant difference was recorded across the four age groups (P < 0.001), the percentiles were analyzed for each age group (each one including subjects from 0 to 11 months within the year of age). The graphical trends of the percentiles by age are reported in Figures 2–4.

Comparison between sector of the canines and angular measurements

A correlation was found between the inclination of the lateral incisor (angle α_i) and the sector of the canine at 8 (P< 0.001) and 9 (P< 0.001) years of age (Table II); a decreased distal inclination of the incisor crown correlated with a more mesially located crown of the erupting canine. Table III shows that a statistically significant association also existed between the inclination of the canine to the adjacent incisor (angle β) and the sector of the canine at 10 (P < 0.001) and 11 years of age (P< 0.001); this inclination increased for more mesially located erupting canine crowns. Lastly, within each age group, the mesial inclination of the canine (angle α_c) generally decreased for more distally located crowns (Table IV).

Associations between the angular measurements

High Pearson's correlation coefficients were found between the inclination of the canine to the adjacent incisor (angle β) and the inclination of the incisor (angle α_i), as well as between the inclination of the canine to the adjacent incisor (angle β) and the inclination of the canine (angle α_c). A statistically significant association (P < 0.001), with no relevant clinical significance (r = 0.147), existed between the inclination of the incisor (angle α_i) and that of the canine (angle α_c). For an inclination of the canine to the adjacent incisor of >28°, a median value for the inclination of the canine of 21° was found, as compared to 11° for the whole sample, while the median value for the inclination of the incisor was 13°, as compared to 8°.

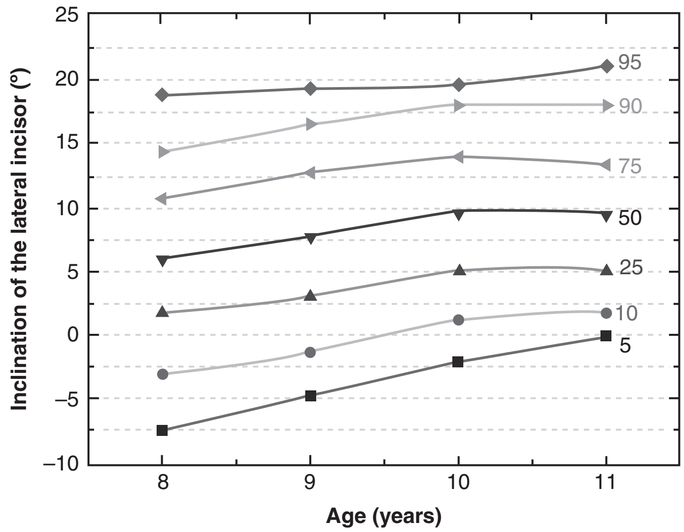

Figure 2. Inclination of the lateral incisors: percentiles by age (interquartile range variation 9–10°).

Association between sector of the canines and age

An association was noted between age and sector relative to the mesiodistal position of the canine cusp tip: the proportion of canines in s2 decreased and that of canines in s1 increased with age.

Reliability

The intra-observer agreement was excellent, with ICC values ranging from 0.98 to 1.00. For inter-observer reliability, ICC values ranged from 0.94 to 1.00, thus demonstrating that the measurement method is not influenced by the clinical experience of the observer. The order of magnitude of the measurement error for the angles was <1°, as compared to a cross-sectional variability of ≈10° (Figures 2–4) and was thus considered negligible.

Discussion

This study demonstrated that the inclination of the lateral incisor (angle α_i) varied during the eruption of the canine. In our population of 1013 children of Caucasian origin from northern Italy, the distal inclination of the crown of the lateral incisors showed an initial increase between 8 and 10 years of age (median values of 6–10°) and remained almost unchanged between 10 and 11 years of age (Figure 2). This observation is in accordance with previous descriptive findings that the 'ugly duckling' stage reaches its maximum at ≈10 years [17,19]. In contrast, it is not in accordance with the previous article by Tsai [20].

We also investigated the inclination of the erupting canines (angle α_c), which showed an initial increase in the mesial inclination of their crown between 8 and 9 years, followed by a decrease

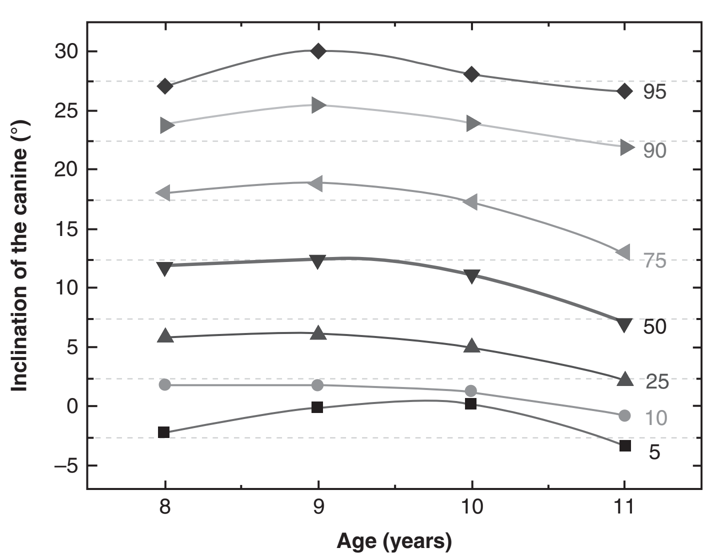

Figure 3. Inclination of the canines: percentiles by age (interquartile range variation: 11–13°).

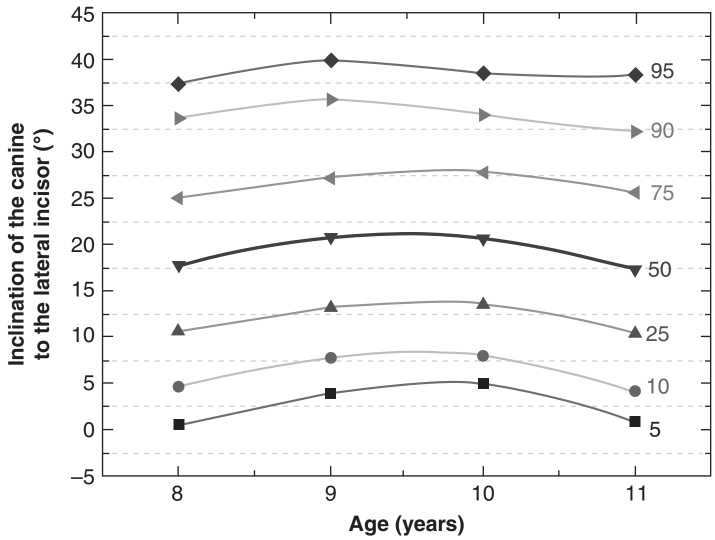

Figure 4. Inclination of the canines to the adjacent lateral incisors: percentiles by age (interquartile range variation: 14–15°).

between 9 and 11 years, with the greatest inclination at 9 years of age (Figure 3), again in accordance with previous findings [9,25]. As a result, the inclination of the canine to the adjacent incisor (angle β) increased between 8 and 9 years (by both increased mesial inclination of the canine crown and distal inclination of the incisor crown), remained almost constant until 10 years, and then decreased between 10 and 11 years of age (Figure 4). In the population of this study, an inclination of the canine to the adjacent incisor (angle β) exceeding 28° coincided with an interval between the 75th and 90th percentiles for each age, thereby confirming the high risk for teeth located at these percentiles according to Ericson & Kurol [21]. By analyzing those high-risk values, we found that the contribution of the mesial inclination of the long axis of the canine was twice that of the distal inclination of the long axis of the incisor. This indicates that the canine crown could show excessive mesial inclination to the midline (already known as a radiographic sign of eruptive disorders [8,15]) even in the absence of an increased distal inclination of the incisor crown, suggesting that there is no relevant correlation between inclination of the erupting canine and inclination of the erupted lateral incisor.

Table II. Association between the median values of inclination of the lateral incisors (angle α_i) and the sector of the canines (s1–s5)[a].

Age group (years)	Sector	No.	Median (degrees)	P
8	3	27	1	<0.001[b]
	2	358	5	
	1	237	8	
9	3	29	3	<0.001[b]
	2	224	6	
	1	221	10	
10	3	19	5	NS
	2	180	10	
	1	266	9	
11	4	7	4	NS
	3	18	10	
	2	141	10	
	1	295	9	

[a]Only one canine was found in s5 in the 11-year-old group, only two canines were found in s4 in the 9-year-old group, and only one canine was found in s4 in the 10-year-old group. No significant statistics could be computed; thus, these canines are not reported in this Table.
[b]Statistically significant at the 0.05 level after Bonferroni correction.

Table III. Association between median values of inclination of the canines to the adjacent lateral incisors (angle β) and sectors (s1–s5)[a].

Age group (years)	Sector	No.	Median (degrees)	P
8	3	27	15	NS
	2	358	17	
	1	237	19	
9	3	29	22	NS
	2	224	21	
	1	221	20	
10	3	19	19	<0.001[b]
	2	180	22	
	1	266	19	
11	4	7	28	<0.001[b]
	3	18	22	
	2	141	20	
	1	295	15	

[a]Only one canine was found in s5 in the 11-year-old group, only two canines were found in s4 in the 9-year-old group, and only one canine was found in s4 in the 10-year-old group. No significant statistics could be computed; thus, these canines are not reported in this Table.
[b]Statistically significant at the 0.05 level after Bonferroni correction.

Table IV. Association between median values of inclination of the canines (angle α_c) and sectors (s1–s5)[a].

Age group (years)	Sector	No.	Median (degrees)	*P*
8	3	27	18	<0.001[b]
	2	358	11	
	1	237	12	
9	3	29	18	<0.001[b]
	2	224	13	
	1	221	10	
10	3	19	15	NS
	2	180	12	
	1	266	10	
11	4	7	27	<0.001[b]
	3	18	19	
	2	141	9	
	1	295	5	

[a]Only one canine was found in s5 in the 11-year-old group, only two canines were found in s4 in the 9-year-old group, and only one canine was found in s4 in the 10-year-old group. No significant statistics could be computed; thus, these canines are not reported in this Table.
[b]Statistically significant at the 0.05 level after Bonferroni correction.

A correlation did exist when evaluating the mesiodistal positioning of the crown of the erupting canine (s1–s5) and the inclination of the incisor (angle α_i); until 9 years, the distal inclination of the lateral incisor crown clearly decreased for more mesially located canine crowns in the alveolar bone (Table II). This is in contrast with the previous statement that the distal inclination of the lateral incisor crown would be due to a mesially and ectopically erupting crown of the canine [3]. This is a new finding, representing a new contribution to the understanding of changes in the inclination of lateral incisors during mixed dentition.

Distal inclination of the crown of the lateral incisor during normal dental development is due to the physiologically close contact with the crown of the erupting canine (that is, canines in s1) [19]. In contrast, the crown of the lateral incisor may not tip distally as a result of an ectopic displacement of the canine crown (that is, canines in s2–s5). This situation can only be explained by the absence of a contact between the incisor and the canine (such as a palatal displacement of the canine) or by the presence of a canine/incisor contact associated with incisor root resorption. It is therefore important to consider that in the presence of a righted crown of the erupted lateral incisor between 8 and 9 years of age, an ectopic intraosseous position of the erupting canine cannot be excluded. For this reason, complementary clinical and radiological investigations should be made in order to diagnose disturbances in eruption.

Finally, between 10 and 11 years of age, the inclination of the canine to the adjacent incisor (angle β) showed a tendency to increase as the canine crown was more mesially located (Table III). This result can be explained by the increase in the inclination of the canine (angle α_c) as the sector increased at the same age (Table IV).

Conclusions

The findings of this study indicate that the distal inclination of the crown of the lateral incisor should be acknowledged as a physiological stage, reaching its maximum point at ≈10 years of age, followed by spontaneous normalization. Such a distal inclination is associated with a crown of the erupting canine located distally to the root of the incisor, and this might be the reason for the registered change in incisor inclination. The clinician will then consider its correction unnecessary at these ages. This emphasizes that not only the orthodontist, but also the pediatric dentist and general practitioner, should be aware of the high risk of iatrogenic initiation of incisor root resorption when an active orthodontic treatment is employed for the correction of anterior misalignment in mixed dentition [17,19,26,27].

So far, it has been suggested that the erupting canine causes a change in the inclination of lateral incisors during mixed dentition, but there are no similar studies in the literature that quantitatively investigate a possible association between the intraosseous position of the canines and inclination of the incisors. The present study indicates that the inclination of the lateral incisor is strongly correlated with the mesiodistal intraosseous position of the erupting canine. Ectopic canines, which are located mesially on panoramic radiographs, result in righting of the long axis of the adjacent lateral incisors, indicating that it is the absence of a distal inclination of the lateral incisor crown that should be acknowledged as a predictive sign of eruptive disorders of the canines.

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