Original Article

Eruptive path of maxillary canines in patients with lateral incisor agenesis: a longitudinal follow-up

João Gabriel Rando Poiani[a]; Gabriela Utrago[a]; Felícia Miranda[b]; Vinícius Augustus Merino da Silva[c]; Ana Cláudia de Castro Ferreira Conti[d]; Daniela Garib[e]

ABSTRACT

Objectives: To evaluate the eruptive angle, mesiodistal position and height of permanent maxillary canines in patients with agenesis of the permanent maxillary lateral incisor (AL) from the mixed to the permanent dentition.

Materials and Methods: The sample was composed of orthodontic records of subjects with and without AL. The agenesis group comprised 11 patients, 7 with bilateral and 4 with unilateral AL (8.6 ± 1.6 years, 4 males, 7 females). The control group comprised 9 patients (8.5 ± 1.0 years, 2 males, 7 females) without AL. Panoramic radiographs were analyzed at three timepoints: intertransitional period (T1), second transitional period (10.1±0.9 years, T2) and permanent dentition (11.9±1.1 years, T3). The long axis angle of the permanent maxillary canine (α and β), the mesiodistal distance (d) in relation to the central incisor, and the height (H) from the cusp tip of the canine to the occlusal plane were evaluated. Intergroup comparisons were performed with t-tests, Mann-Whitney, and Chi-square tests ($P < 0.05$).

Results: A mesial position of the canine cusp tip relative to the distal of the permanent maxillary central incisor was observed for the agenesis group at T1, T2 and T3. From T1 to T2, the agenesis group showed greater occlusal displacement of the canine tooth germ.

Conclusions: In patients with AL, canine tooth germs showed more mesial displacement and erupted a mean of 4.5 mm closer to the maxillary central incisors. Eruption of maxillary canines tended to be accelerated during the late mixed dentition in patients with AL. (*Angle Orthod*. 2025;95:19–26.)

KEY WORDS: Orthodontics; Anodontia; Canine tooth; Longitudinal study

INTRODUCTION

Management of dental agenesis is considered a challenge in orthodontic clinical practice. Permanent tooth agenesis comprises the most frequent dental anomaly and affects females more often than males.[1,2] Permanent maxillary lateral incisors are the third most commonly affected teeth, after third molars and mandibular second premolars, with an average prevalence of 4%.[2] This dental anomaly can be associated with other genetically induced dental phenotypes, including small teeth, delayed dental development and many types of ectopic eruption.[3] When tooth agenesis occurs in association with other dental anomalies, it constitutes a pattern of dental anomalies.[4]

The absence of lateral incisors affects dental occlusion, smile esthetics, phonetics and function.[5] The main treatment options for maxillary lateral incisor agenesis include space maintenance for prosthetic rehabilitation or space closure with canine substitution.[6–8] Treatment planning also takes into account the sagittal interarch

[a] Master's Student, Department of Orthodontics, Bauru Dental School. University of São Paulo, Bauru, São Paulo, Brazil.

[b] Assistant Professor, Department of Orthodontics, Bauru Dental School, Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Bauru, São Paulo, Brazil.

[c] PhD Student. Department of Orthodontics, Bauru Dental School. University of São Paulo, Bauru, São Paulo, Brazil.

[d] Assistant Professor, Department of Orthodontics, Bauru Dental School. University of São Paulo, Bauru, São Paulo, Brazil.

[e] Professor, Department of Orthodontics, Bauru Dental School, Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Bauru, São Paulo, Brazil.

Corresponding author: Dr. João Gabriel Rando Poiani, Department of Orthodontics, Bauru Dental School, University of São Paulo, Alameda Octávio Pinheiro Brisolla 9-75 Bauru, SP 17012-901, Brazil.
(e-mail: joaorandopoiani@gmail.com)

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relationship, dental arch-tooth size discrepancies, orthodontic treatment time and patient/family expectations.[9] The eruption position of the canine adjacent to the lateral incisor position is an important factor for the decision-making process, considering that a mesial position is more favorable for canine substitution.

The permanent maxillary canine typically emerges into the oral cavity between 10 and 12 years of age.[10] Under normal conditions, the crown of the permanent maxillary canine gently touches the root of the permanent lateral incisor during eruption.[11] The canine eruptive path is influenced by genetics, the space available in the dental arch and, also, by the presence and size of the permanent maxillary lateral incisors.[12–15] However, there is no longitudinal information in the literature regarding the eruption path of maxillary permanent canines when adjacent lateral incisors are absent. It would be useful to know whether mesial displacement of the adjacent erupting canine occurs and, if so, by how much, and whether excessive mesial tipping of the canine occurs.

Therefore, the aim of this study was to evaluate changes in the eruptive angle, mesiodistal position and height of the permanent maxillary canine in patients with agenesis of the permanent maxillary lateral incisor, from the mixed to the permanent dentition. The null hypothesis was that permanent maxillary canines exhibited a similar eruptive path in the presence or absence of an adjacent lateral incisor.

MATERIALS AND METHODS

This retrospective, longitudinal study was approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo, Brazil (protocol number 75828823.9.0000.5417).

The sample of this study included panoramic radiographs of orthodontic patients from the files of Bauru Dental School, University of São Paulo, Brazil. The orthodontic records of 2566 patients who sought phase I orthodontic treatment from 1987 to 2017 were analyzed.

The inclusion criteria were: presence of panoramic radiographs in middle and late mixed dentition and in the permanent dentition, agenesis of at least one permanent maxillary lateral incisor, and clearly distinguishable condyles for reference point placement. Exclusion criteria were: agenesis or ectopic eruption of maxillary canines, presence of craniofacial anomalies/syndromes, and agenesis of permanent maxillary premolars.

Sixteen patients exhibited agenesis of at least one maxillary lateral incisor. Four patients were excluded due to inadequate quality of panoramic radiographs. Another patient was excluded due to agenesis of the permanent maxillary first and second premolars. The final agenesis group (AG) comprised 11 patients (4 male, 7 female) with an initial mean age of 8.6 years (SD = ± 1.69). Seven patients had bilateral and four had unilateral lateral incisor agenesis, comprising 18 analyzed teeth. At the baseline, the maxillary deciduous canines were present in all hemi-arches with permanent maxillary lateral incisor agenesis. The deciduous lateral incisor on the side of tooth agenesis was present in 13 out of 18 hemi-archs. There was no report of agenesis of deciduous lateral incisors or extraction in the dental files.

The control group comprised 9 subjects (2 male, 7 female) randomly selected from the sample of 2550 subjects without agenesis of permanent maxillary lateral incisors for whom tooth germs of maxillary canines were evaluated bilaterally (Figure 1). The mean initial age of the control group was 8.5 years (SD = ± 1.0).

The panoramic radiographs were evaluated at three timepoints: during the inter-transitional period of the mixed dentition (when permanent first molars and all incisors were fully erupted) at a mean age of 8.59 ± 1.37 (T1), second transitional period of the mixed dentition at a mean age 10.17 ± 0.93 (T2), and during the early permanent dentition (T3; mean age 11.93 ± 1.12). Panoramic tracings and measurements were manually performed using acetate paper, pencil, X-ray illuminator, ruler and protractor.

In both groups, the following variables were analyzed at T1, T2 and T3 (Figure 2):

- The angle between the long axis of the permanent maxillary canine and a line drawn between the upper edge of the condyles (α).[16]
- The angle between the long axis of the permanent maxillary canine and the long axis of the permanent maxillary central incisor on the same side (β).
- The mesiodistal distance (d) between the cusp tip of the permanent maxillary canine and a line perpendicular to the bi-condylar plane passing along the distal aspect of the permanent maxillary central incisor on the same side.
- The height (H) was measured as the distance between the cusp tip of the permanent maxillary canine and a horizontal line passing through the distal cusp tip of the permanent maxillary first molar and the center of the incisal edge of the permanent maxillary central incisor on the same side (defining the occlusal plane).

Statistical Analysis

A post-hoc power analysis was performed using the GPower software (Version 3.1.9.7, Heinrich-Heine-University, Düsseldorf, Germany).

After at least 1 month, all panoramic radiographs were remeasured by the same examiner. The reliability

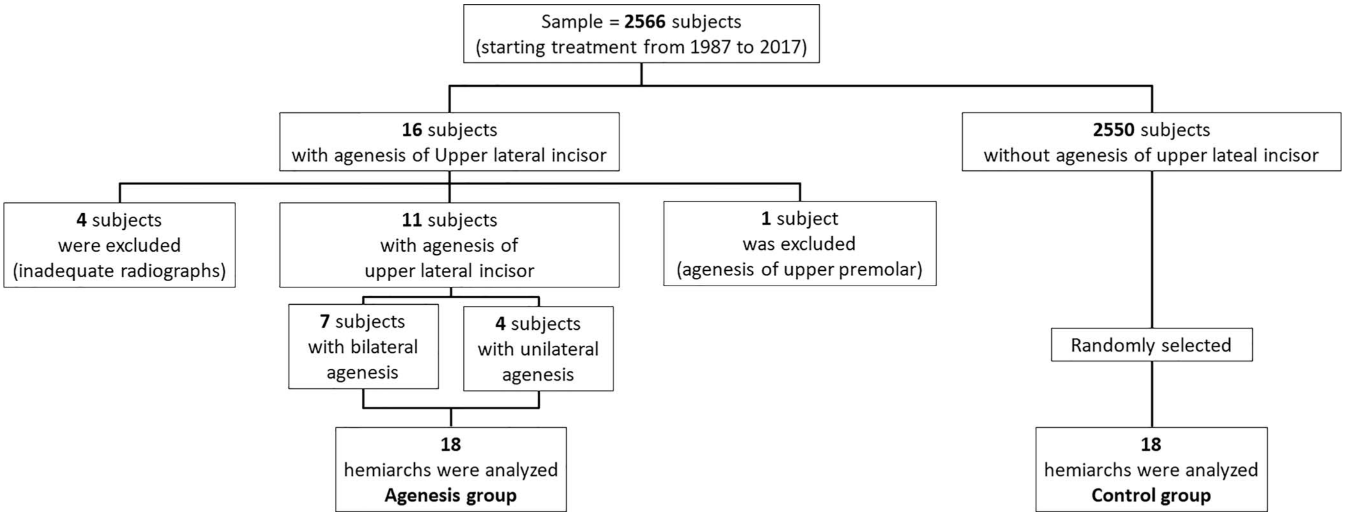

Figure 1. Enrollment process.

of repeated measures was assessed using the intraclass correlation coefficient (ICC).

Shapiro Wilk test was used to verify the normal distribution. Intergroup comparisons of sex distribution and initial age were performed using chi-square test and t test, respectively. Intergroup comparisons of quantitative variables were performed using Student t test and Mann-Whitney test. Interphase comparisons were performed using Student t tests. A statistical significance level of 5% was adopted for all tests. Statistical analyses were carried out using Jamovi software (version 2.2.5; https://www.jamovi.org.).

RESULTS

The achieved power was 89%, considering a 5% significance level and a mean change in the variable "d" of -0.64 (SD $=$ 1.68) and 1.82 mm (SD $=$ 2.66) for the agenesis group and control group, respectively. The effect size was 1.10.

Adequate reproducibility was found for all variables with ICC varying from 0.885 (β angle) to 0.994 (d distance).

The baseline intergroup comparisons are shown in Table 1. No significant intergroup difference was observed for sex distribution and mean initial age.

No intergroup difference was observed for canine mesial angulation (α and β) and height (H), at the three timepoints. The difference between groups was observed only for variable "d" at T1, T2 and T3, revealing mesial displacement of the maxillary canines in the agenesis group compared to the control group (Table 2). Figures 3 to 6 show the changes in each measurement during follow-up.

Table 3 demonstrates the intergroup comparisons of interphase changes. From T1 to T2, the canines moved toward the mesial in the agenesis group and toward the distal in the control group ($P = 0.034$). In the mixed dentition (T1-T2), greater eruptive movement was observed in the agenesis group compared to the control group ($P = 0.031$). Over the complete period of observation (T3-T1), the distal movement of canines was greater in the control group. (P=0.043).

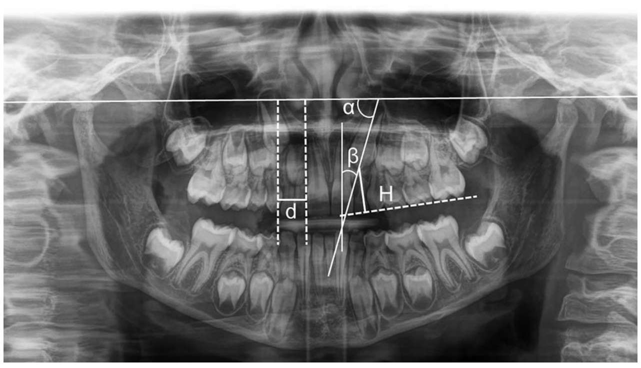

Figure 2. Measurements performed on the panoramic radiographs. α: angle between the long axis of the canine and a line tangent to the upper edge of the condyles; β: angle between the long axis of the canine and the long axis of the permanent maxillary central incisor in the same hemi-arch; d: distance between the canine and the distal surface of the permanent maxillary central incisor in the same hemi-arch; H: distance between the cusp tip of the canine and the occlusal plane.

Table 1. Intergroup Comparison (*t* Test and Chi-square Test)

Variable	Agenesis Group	Control Group	*P* Value
Sex, subjects n			
Male	4	2	0.248‡
Female	7	7	
Total subjects, n	11	9	
Total hemiarchs	18	18	—
Initial Age (n/sd)	8.66 (1.69)	8.5 (1.0)	0.805†

Statistically significant at *P* less than 0.05. †: t-test; ‡: Chi-square test.

Table 2. Intergroup Measurements and Comparisons (*t* Test and Mann-Whitney Test)

Variable	Agenesis Group Mean (SD)	Control Group Mean (SD)	Mean Difference	95% CI		*P* Value
				Lower	Upper	
Inter-transitional period						
α T1 (°)	74.07 (13.64)	75.24 (7.00)	1.16	−7.49	9.82	0.783†
β T1 (°)	12.5 (11.98)	14.59 (6.83)	2.01	−5.87	10.05	0.592†
d T1 (mm)	4.57 (1.43)	6.85 (2.39)	2.28	0.26	4.30	0.029*†
H T1 (mm)	17.4 (4.20)	16.0 (2.40)	−1.42	−4.22	1.36	0.300†
Second transitional period						
α T2 (°)	76.22 (8.15)	80.53 (5.91)	4.31	−0.516	9.13	0.078†
β T2 (°)	14.28 (9.23)	10.11 (6.45)	4.17	−9.563	1.23	0.126†
d T2 (mm)	4.17 (2.91)	8.64 (2.08)	4.47	0.843	2.759	<0.001*†
H T2 (mm)	11.7 (3.74)	12.4 (2.85)	0.72	−1.53	2.98	0.519†
Permanent dentition						
α T3 (°)	89.56 (4.17)	90.22 (4.74)	0.66	−2.48	3.80	0.660†
β T3 (°)	−1.16 (6.81)	−0.11 (4.02)	1.04	−2.81	4.90	1.045†
d T3 (mm)	6.03 (3.15)	10.52 (1.42)	4.49	3.50	6.50	<0.001*‡
H T3 (mm)	0.11 (0.45)	0.10 (0.51)	−0.008	−0.47	0.45	0.972†

* Statistically significant at *P* less than 0.05; †: t-test; ‡: Mann-Whitney. α: angle of the long axis of canine and a line between the upper edge of the condyles; β: angle between the long axis of canine and the long axis of permanent maxillary central incisor in the same hemiarch; d: distance between canine and the distal of the permanent maxillary central incisor in the same hemiarch; H: distance between the cusp tip of canine and occlusal plane. A positive value for the Alpha angle indicates mesial angulation of the canine crown and a negative value indicates distal angulation. A positive value for the Beta angle indicates divergence of the roots of the canine and the central incisor and a negative value indicates convergence of the roots.

DISCUSSION

Maxillary canines appear to have a different eruptive path when there is agenesis of the neighboring lateral incisor. To evaluate the angulation of the maxillary permanent canine on its eruptive path (α angle), previous studies used both skeletal[16,17] and dental planes[18] as references. The most common skeletal references in the literature were the bicondylar[16] and suborbital plane[17]. In the current study, a horizontal line passing tangent to the upper limit of the condyles bilaterally was used as a reference due to its clear visualization in panoramic radiographs.[16] Dental references, such as the occlusal plane, might be less stable in a longitudinal assessment.[18–20] Evaluation using the bicondylar line as a reference has proven to be the most reliable method for analyzing the alpha angle.[21] In addition, to measure the β angle and the distance (d), an adaptation of the measurement proposed by Ericson and Kurol[22] was used. Even though the measurements were performed manually using conventional panoramic radiographs, an adequate level of reproducibility was achieved for all variables.

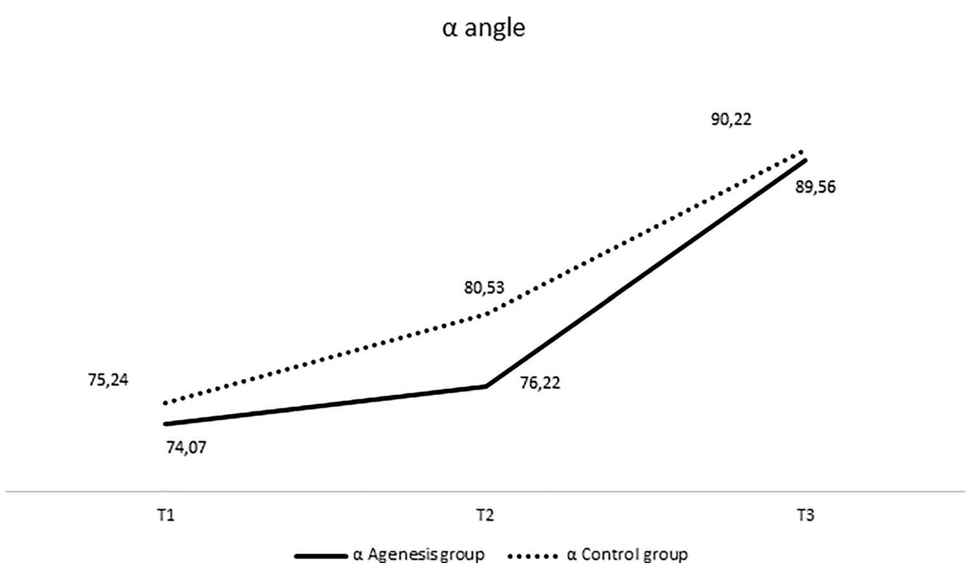

Figure 3. Changes in the α angle from T1 to T3.

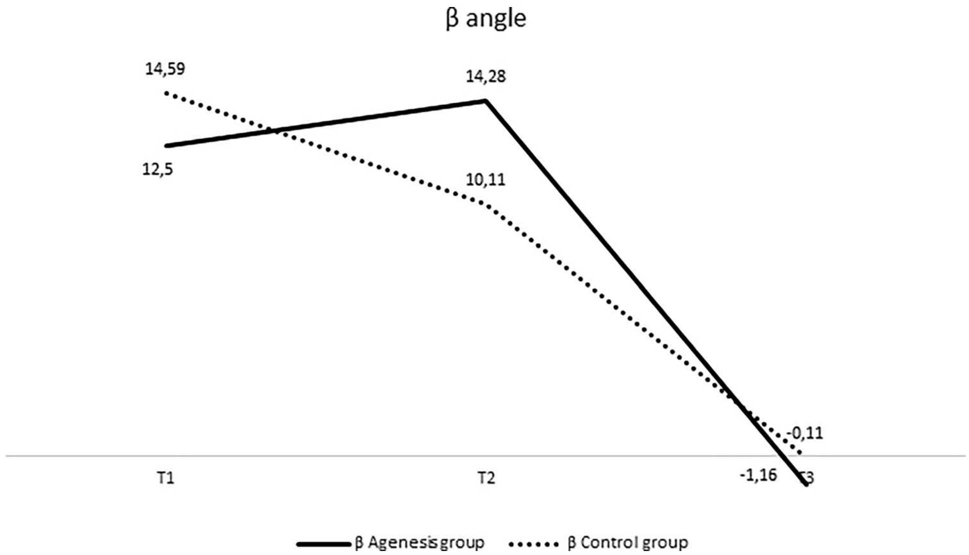

Figure 4. Changes in the β angle from T1 to T3.

The mesiodistal angulation of maxillary canines in the hemi-arch with lateral incisor agenesis was similar to the control group without agenesis in both the mixed and permanent dentition. During the follow-up period, an uprighting movement of the maxillary canines occurred similarly in both groups. No previous study has evaluated longitudinally the angulation of maxillary canines in cases of lateral incisor agenesis. Warford et al.[16] observed that maxillary canines displayed an angulation of approximately 75° during the mixed dentition in patients without lateral incisor agenesis. A recent study also reported uprighting movement of the maxillary permanent canines from 8 to 14 years of age in subjects without an absence of teeth.[23]

The maxillary canine exhibited a more mesial position in the agenesis group compared to the control group. Both in the mixed and permanent dentition, the distance between the canine cusp tip and the distal aspect of the permanent maxillary central incisor was significantly smaller in the agenesis group than in the control group. In subjects with lateral incisor agenesis, the maxillary canines naturally displaced toward the neighboring central incisors. The maxillary canines erupted in the dental arch displaying a mean mesial displacement of 4.5 mm. In the control group, a mean distance between maxillary canines and central incisors of 6.85mm was observed in the mixed dentition, corresponding to the mean mesiodistal width of maxillary permanent lateral incisors.[24] These results were

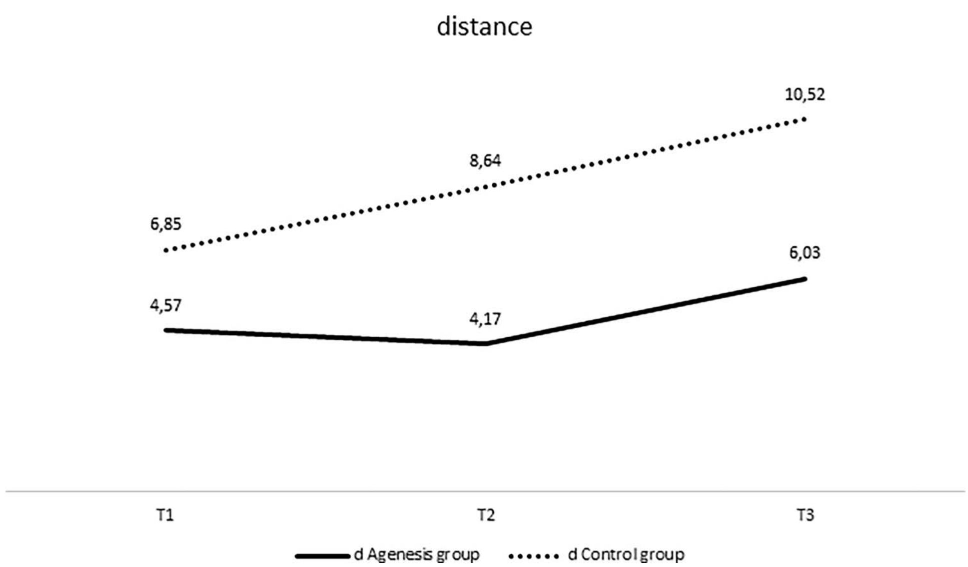

Figure 5. Changes in the distance (d) from T1 to T3.

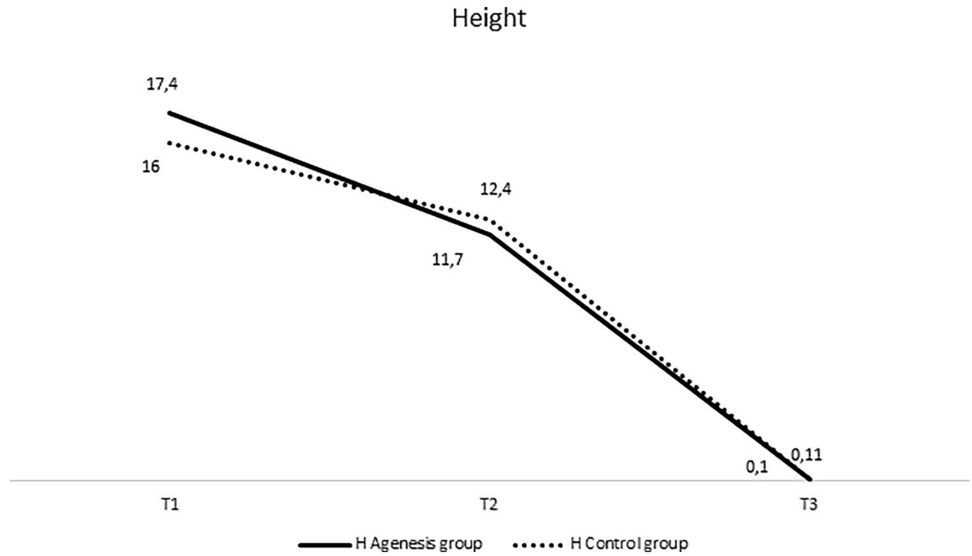

Figure 6. Changes in the height (H) from T1 to T3.

in agreement with a previous cross-sectional study showing a mesial position of maxillary canine germs in patients with unilateral and bilateral agenesis of permanent lateral incisors.[25]

The pattern of mesiodistal movement of canine tooth germ in the agenesis group was distinct from the control group. In patients with lateral incisor agenesis, maxillary canines moved toward the mesial in the mixed dentition and toward the distal from the late to the permanent dentition. Conversely, in the control group, a constant distal movement of the canine tooth germ was observed from the mixed to the permanent dentition and might have been related to both the distoangulation of the maxillary lateral incisors during the "ugly duckling" phase and to maxillary canine uprighting movement. These results were in agreement with a previous study demonstrating distal movement of the maxillary canine from 7 to 14 years of age.[26] The mesial movement of canine tooth germs in the agenesis group is explained by the lack of the lateral incisor root working as a guide. It is rare to find crowding in patients with agenesis but, in cases of crowding, it may be presumed that the upper canines would migrate more mesially to accommodate space deficits.[27]

Analyzing canine height, no difference was found between the agenesis and control groups at any

Table 3. Intergroup Comparison of Interphase Changes (*t* Test)

Diference	Agenesis Group Mean (SD)	Control Group Mean (SD)	Mean Difference	95% CI Lower	95% CI Upper	*P* Value
T2 – T1						
α (°)	5.35 (7.58)	5.15 (9.46)	−0.21	−8.57	8.16	0.959
β (°)	−3.57 (6.18)	−4.24 (6.44)	−0.66	−6.59	5.27	0.819
d (mm)	−0.64 (1.68)	1.82 (2.66)	2.46	0.19	4.73	0.034*
H (mm)	−6.43 (3.95)	−3.35 (2.50)	3.08	0.313	5.84	0.031*
T3 – T2						
α (°)	13.00 (6.97)	9.69 (4.80)	−3.36	−7.51	0.77	0.107
β (°)	−14.91 (9.09)	−10.22 (7.84)	4.68	−1.23	10.59	0.116
d (mm)	1.91 (3.21)	1.89 (2.84)	−0.01	−2.13	2.093	0.987
H (mm)	−10.9 (3.45)	−12.6 (2.81)	−1.69	−4.48	1.10	0.222
T3 – T1						
α (°)	14.85 (9.99)	15.00 (8.97)	0.14	−8.48	8.77	0.973
β (°)	−11.35 (7.65)	−14.65 (8.39)	−3.29	−10.92	4.34	0.381
d (mm)	0.92 (1.92)	3.68 (3.13)	2.74	0.09	5.40	0.043*
H (mm)	−17.3 (4.30)	−15.9 (2.32)	1.38	−1.40	4.17	0.314

* Statistically significant at *P* less than 0.05. α: angle of the long axis of canine and a line between the upper edge of the condyles; β: angle between the long axis of canine and the long axis of permanent maxillary central incisor in the same hemiarch; d: distance between canine and the distal of the permanent maxillary central incisor in the same hemiarch; H: distance between the cusp tip of canine and occlusal plane. Positive values indicate that the value increased, and negative values indicate that the value decreased between the evaluated time points.

timepoint. However, the eruptive movement during the mixed dentition (T1-T2) was greater in the absence of lateral incisors (Table 3). In patients with lateral incisor agenesis, the maxillary canines tended to move toward the occlusal plane faster during the mixed dentition. It may be speculated that these intergroup differences could be explained by the availability of space in the dental arch in patients with lateral incisor agenesis, which favors eruptive acceleration when the canine has at least half of the root formed. The methodology used in this study did not allow evaluation of the mean age of maxillary canine eruption in each group and this was a limitation of the study. No information on the timing of maxillary canine eruption was found in the literature in patients with agenesis of the neighboring lateral incisor. Most previous studies evaluating the relationship between agenesis of the maxillary incisor and maxillary canines were focused on ectopic eruption, including palatal displacement and transposition, rather than documenting physiologic eruption.[15,28–31] No information regarding the physiologic eruption timing and path of maxillary canines in patients with an absent maxillary permanent lateral incisor was found for comparison.

The development of maxillary canines in patients with lateral incisor agenesis was mesially displaced, with a tendency for accelerated eruptive movement toward the dental arch. These results are important for providing reference to clinicians regarding the normal eruption path of maxillary canines in patients with lateral incisor agenesis.

A split-mouth design would be ideal for comparison between the sides with and without lateral incisor agenesis because the eruption path of the canine may be influenced by other factors such as dental crowding. However, the small subsample of unilateral cases did not permit this type of analysis in the current study. Future longitudinal and multicenter studies should be performed using a large sample with unilateral agenesis of maxillary lateral incisors.

CONCLUSIONS

- The eruptive path of the maxillary canine when there is agenesis of the adjacent lateral incisor differs from subjects without tooth agenesis.
- In patients with agenesis of maxillary lateral incisors, canine tooth germs displayed mesial displacement and erupted a mean of 4.5 mm closer to the maxillary central incisors.
- Similar mesiodistal angulation and height of maxillary canines were observed in cases with and without lateral incisor agenesis.
- The eruption of maxillary canines tended to be accelerated during the late mixed dentition in cases with absent maxillary lateral incisors.

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