Association between palatally displaced maxillary central incisors and lateral incisors: A retrospective cone-beam computed tomographic study

Chandradev Bhikoo, Huihuang Ye, Tingting Chen, Leqi Zhang, Guosheng Wu, Ah Kong Junior Leung Wing Chung, Gerald Volière, and Rongdang Hu
Zhejiang, People's Republic of China

Introduction: The objective of this study was to investigate the location, orientation and root development of maxillary lateral incisors in patients with palatally impacted central incisors. Comparison was made between the lateral incisor on the affected side and that on the normally erupted side. **Methods:** Cone-beam computed tomographic images from 20 patients (10 boys, 10 girls, mean age (9.01 ± 1.52 years old) with unilateral palatally impacted maxillary central incisors were imported into Dolphin imaging software 11.8 for 3-dimensional reconstruction and reorientation. Software measurement tools were used to measure the root length, crown distance, angle to palatal plane, distance to midline, and angle to midsagittal plane of the maxillary lateral incisors on both the impacted and unaffected sides. **Results:** The Wilcoxon signed rank test indicated that lateral incisors on the impacted side were more proclined, at a mean angle difference of 29.47° in the sagittal plane ($P < 0.001$). The mean length of the roots of the lateral incisors was 1.21 mm shorter ($P < 0.05$) on the affected side compared with the normal side, and the lateral incisor crowns on the impacted side were located at an average of 4.57 mm closer to the palatal plane than on the normally erupted side ($P < 0.001$). The angle of long axis of the lateral incisors on the affected side had a greater angulation to the midsagittal plane compared with the unaffected side, with a mean difference of 30.27° ($P < 0.001$). **Conclusions:** Maxillary lateral incisors adjacent to palatally impacted maxillary central incisors side had abnormal root development and demonstrated angulation and position change compared with those adjacent to normally erupted central incisors. (Am J Orthod Dentofacial Orthop 2019;156:44-52)

With a rare occurrence rate of 0.06%-0.2%,[1] ectopic maxillary central incisors can be categorized based on their 3-dimensional orientation: labially, palatally, or vertically impacted. Palatal impaction is suspected when the lower posterior angle of the long axis of a tooth to the palatal plane is <90° (Fig 1).[2] This typical orientation is mainly a consequence of trauma to the deciduous incisors when the permanent incisors are located lingual and superior to their apices, during the early calcification of the tooth crown. A blow of considerable extent during this early stage of development results in lingual avulsion of the crown of the incisor and labial displacement of the roots, accompanied by tooth intrusion in most cases.[3]

Impacted teeth lead to serious problems such as irregular dentition, diastema, incisor transposition, and root resorption of adjacent teeth.[4] Several studies carried out on maxillary lateral incisors attributed a change in their normal position, orientation, and dimension to the presence of a palatally impacted maxillary canine on the ipsilateral side.[5-9] Jacobs et al suggested that palatally impacted canines impinge on the root of the lateral incisor, leading to retroclination in the sagittal plane.[7] Shapira explained that palatally displaced canines can cause the crown of lateral incisors to tip distally and rotate.[8] Liuk et al concluded that palatally impacted canines were associated with smaller lateral

Department of Orthodontics, School and Hospital of Stomatology, Wenzhou Medical University, Wenzhou, Zhejiang, People's Republic of China.
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Address correspondence to: Rongdang Hu, Institute of Stomatology, School and Hospital of Stomatology, Wenzhou Medical University, No 113 West Xueyuan Road, Wenzhou, Zhejiang, People's Republic of China; e-mail, hurongdang@hotmail.com.
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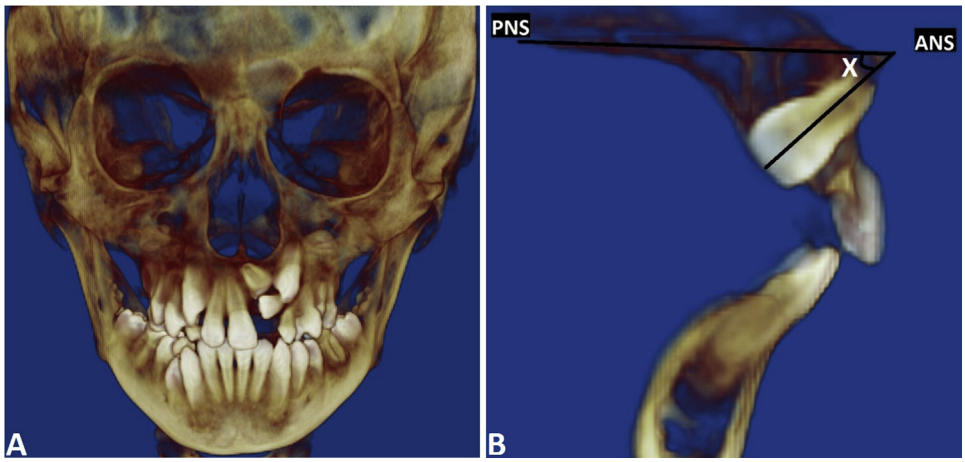

Fig 1. A, Frontal view after 3-dimensional reconstruction. **B,** Sagittal slice of a palatally impacted maxillary central incisor, obtained with the use of CBCT, showing the long axis of crown to the palatal plane <90°.

incisors and palatal tipping of the crown.[5,6] However, no study has explored the influence of adjacent palatally impacted maxillary central incisors on lateral incisors owing to their being the rarest occurrence among impacted incisors and owing to the limitation of conventional radiography in precisely assessing dental images. Since its recent introduction in dentistry, the application of cone-beam computed tomography (CBCT) in the diagnosis and treatment of impacted teeth has become increasingly indispensable as it provides multiple planes for accurately identifying 3-dimensional landmarks of dental structures with submillimeter resolution and allows for precise assessment of teeth, at a low radiation dosage, without blurring and overlapping of adjacent teeth and structures.[10-12] The aim of the present study was to use CBCT to analyze the location, orientation, and root development of maxillary lateral incisors and to compare the variables between the group with palatally displaced central incisors and the control group. The null hypothesis was that there is no difference between the lateral incisors on the affected side and those on the normal side.

MATERIAL AND METHODS

Out of a total of 25 subjects who presented at the Department of Orthodontics, School and Hospital of Stomatology, Wenzhou Medical University, Wenzhou, Zhejiang, China, from January 2012 to October 2017, for palatal impacted maxillary central incisors, 20 patients (10 boys and 10 girls), with mean age 9.01 ± 1.52 years, were recruited for our study. The selected patients met the following inclusion criteria: (1) diagnosed with unilateral palatal impacted maxillary central incisor, defined as the tooth having a lower posterior angle of the long axis of its crown to the palatal plane of <90° (Fig 1), (2) presence of normally erupted contralateral maxillary central incisor, (3) full clinical documentation, contact information, and medical history (dental trauma and dental treatment history), (4) good-definition CBCT images to ensure measurement accuracy, and (5) informed consent signed by parents or guardians. The exclusion criteria were (1) presence of more than 1 impacted tooth in the anterior dentition, (2) serious oral and maxillofacial diseases, craniofacial anomalies, cysts, or cleft lip and palate, and (3) systemic diseases. Approval was obtained from the Ethics Committee of our hospital and university.

Three-dimensional CBCT scans were made for each subject with the use of a Newtom device (QR, Verona, Italy) during the preliminary diagnosis with the following imaging parameters: 110 kV, 1-20 mA (pulse mode), and 26-second scanning time with an axial thickness of 0.25 mm, 15 × 15 cm field of view, and 0.30 × 0.25 mm voxel size. The data, generated in DICOM format from an NNT workstation (QR), were imported into Dolphin imaging 3D software version 11.8 (Patterson Supply, Saint Paul, Minn) for reorientation and measurements.

The 3 reference planes (sagittal, coronal, and axial) were adjusted as defined by Togashi et al[13] to correct errors caused by different head orientations while taking CBCT images. The midsagittal plane was further adjusted according to method C defined in the study by Lee et al.[14] Appropriate magnification was performed for clearer view during the following measurements carried out on the lateral incisors in both the impacted

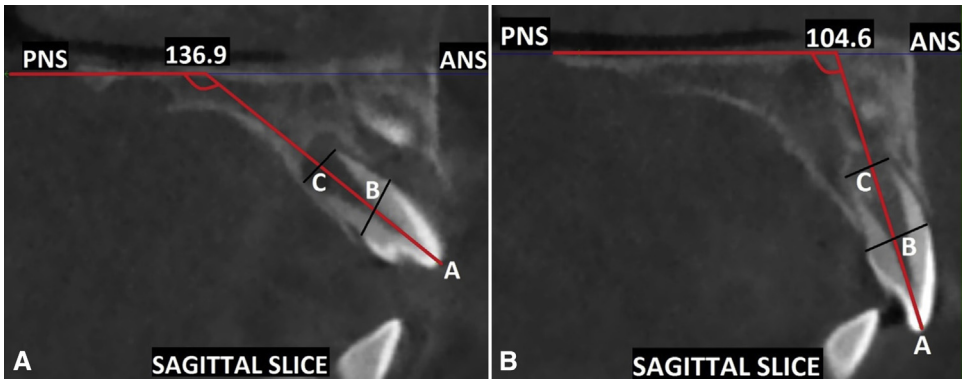

Fig 2. Measurement of angle to palatal plane and length of lateral incisor in **A,** impacted side and **B,** normally erupted side.

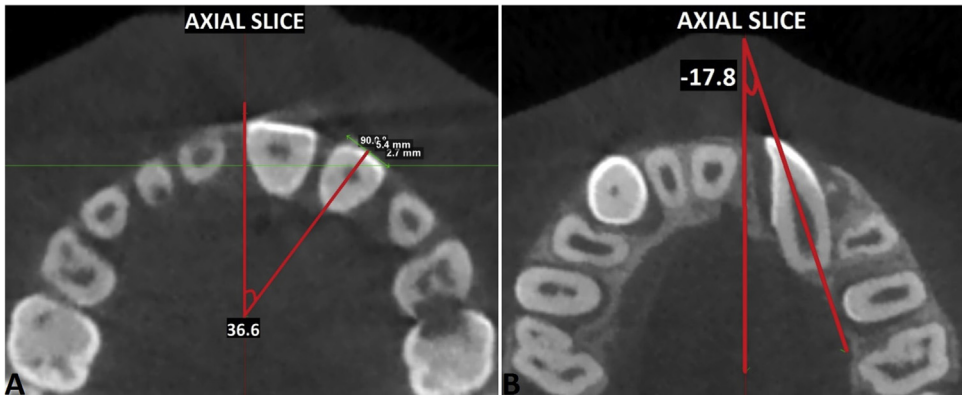

Fig 3. Angle to midline measured on axial slices obtained from CBCT; **A,** The incisor is directed away from the midline, having a positive value. **B,** The incisor is directed toward the midline, having a negative value.

and control groups, using the Dolphin measurement tools with a precision of 0.1 mm for better accuracy: (1) angle to palatal plane, defined as the lower posterior angle between the long axis of the crown (AB), a line drawn from the midpoint of the incisal edge (A) to the middle point of the CEJ (B). and the palatal plane (PNS-ANS), as shown in Figure 2[15]; (2) crown distance, measured in mm, defined as the vertical distance from the incisal tip (A) of the maxillary lateral incisors and the palatal plane[16] (Fig 2); (3) angle to midsagittal plane measured between the midsagittal plane and the long axis of the crown of the lateral incisors on axial slice view, recorded as positive if the crown was directed away from the midsagittal plane (Fig 3, *A*) and negative if tipping toward the midsagittal plane (Fig 3, *B*); and (4) distance to midline (mm) defined as the horizontal distance between the most mesial point on the mesial marginal ridge of the crown and the midsagittal plane.[17]

The reference planes were then reoriented with the long axis of the root of the lateral incisor coinciding with the sagittal plane (Fig 4), for measurement of the length of the lateral incisor root. Root length was measured in mm from the root apex (C) to the middle point of the lingual and palatal aspect of the cementoenamel junction (B) on the sagittal slice at which the lateral incisor root had the maximum labial-lingual width.[18] A summary of the reference points is presented in Table I.

Statistical analysis

All measurements were done by 2 examiners (C.B., H.H.) and were repeated at 2-week intervals. The values of the 2 investigators were averaged for all statistical analyses to reduce random error and were expressed as means and standard deviations. Interrater reliability between the 2 operators was assessed by means of the Bland-Altman method.[19] The measurement data were analyzed for normality with the use of a normal probability plot, and a Wilcoxon signed rank test was carried

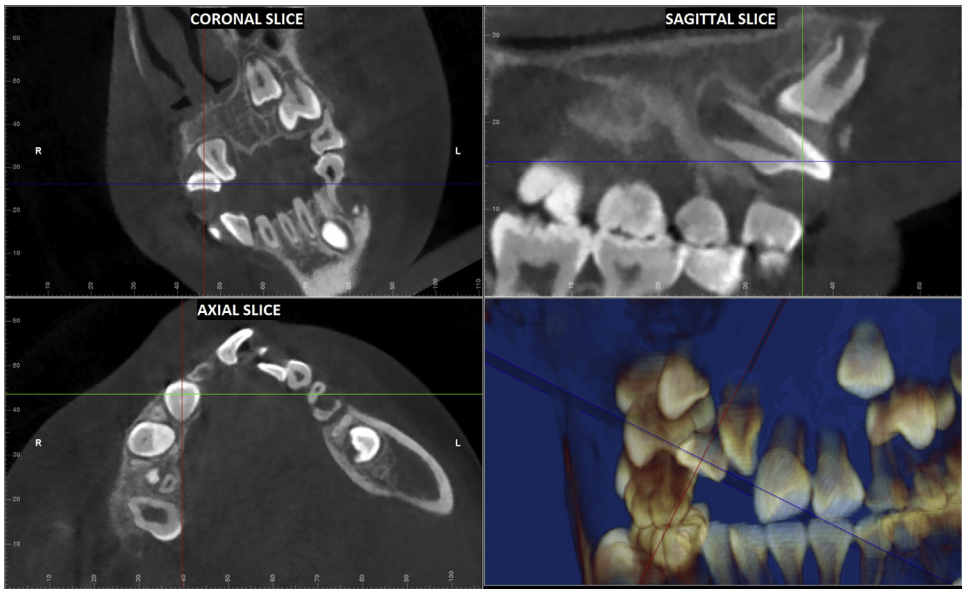

Fig 4. Three-dimensional, coronal, sagittal, and axial views of lateral incisor after reorientation for measurement of root length.

Table I. Definition of landmarks

Reference point	*Definition*
A	Midpoint of incisal edge of lateral incisor
B	Midpoint of line connecting CEJ at labial side and CEJ at palatal side
C	Midpoint of labial part of root apex and palatal part of root apex

CEJ, cementoenamel junction.

out to compare the lateral incisors of the impacted group with those of the normal group. The measurement variables analyzed were crown distance, angle to palatal plane, root length, distance to midline, and angle to midsagittal plane. All P values (2 tailed) <0.05 were defined as significant. Pearson correlation was determined among the 5 variables of the lateral incisor on the impacted side to determine the relationship between them. Pearson correlations were further determined for both groups to analyze correlation of root length and crown distance with age. All statistical analyses were performed with the use of SPSS statistical software (version 17.0; SPSS, Chicago, Ill).

RESULTS

The results for the Bland-Altman plot for interrater and intrarater reliability are presented in Figures 5 and 6, respectively. Average error and limits of agreement for intraobserver error are presented in Table II. Descriptive statistics are presented in Table III. Five variables of 20 lateral incisors were compared between the impacted group and the control group (Figs 7 and 8) with the use of the Wilcoxon signed rank test. Table IV presents significant differences between 4 of the 5 measured variables ($P < 0.05$). It was found that the lateral incisors on the impacted side had a 1.21 mm shorter average root length ($P < 0.05$; $t = -3.13$) compared with the lateral incisors found on the contralateral side. The lateral incisors on the impacted side were found to be more proclined in the sagittal plane by an average angulation of 29.47° ($P < 0.001$). Average crown distance of the lateral incisors on the impacted side was 16.99 ± 4.12 mm, located at an average distance of 4.57 mm closer to the palatal plane ($P < 0.001$; $t = -4.36$), compared with their contralateral counterparts. Angle of long axis of the lateral incisor crown to midsagittal plane was smaller on the impacted side and had a negative mean difference value of 30.27° ($P < 0.001$; $t = -4.97$). No significant statistical difference was found for the distance to midline between the lateral incisor of the impacted and normal sides ($P > 0.05$).

Pearson correlations of the 5 variables of the lateral incisor on the impacted side are presented in Table V, and the significant correlations are shown by means of scatter plots in Figure 9. Cohen[20] suggested that values of 0.5-1.0 are highly correlated and that values of 0.3-0.49 are moderately correlated. Angle of the lateral incisor to the midsagittal plane was found to be highly

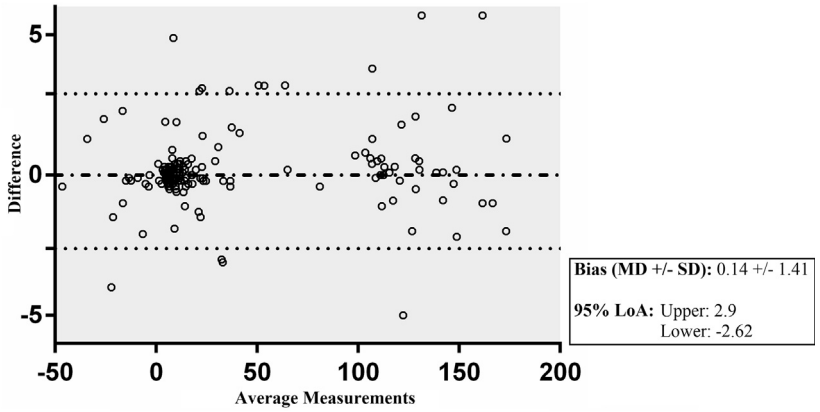

Fig 5. Analysis of agreement with the use of a Bland-Altman plot to show the interrater reliability variability of measurements of the 5 variables.

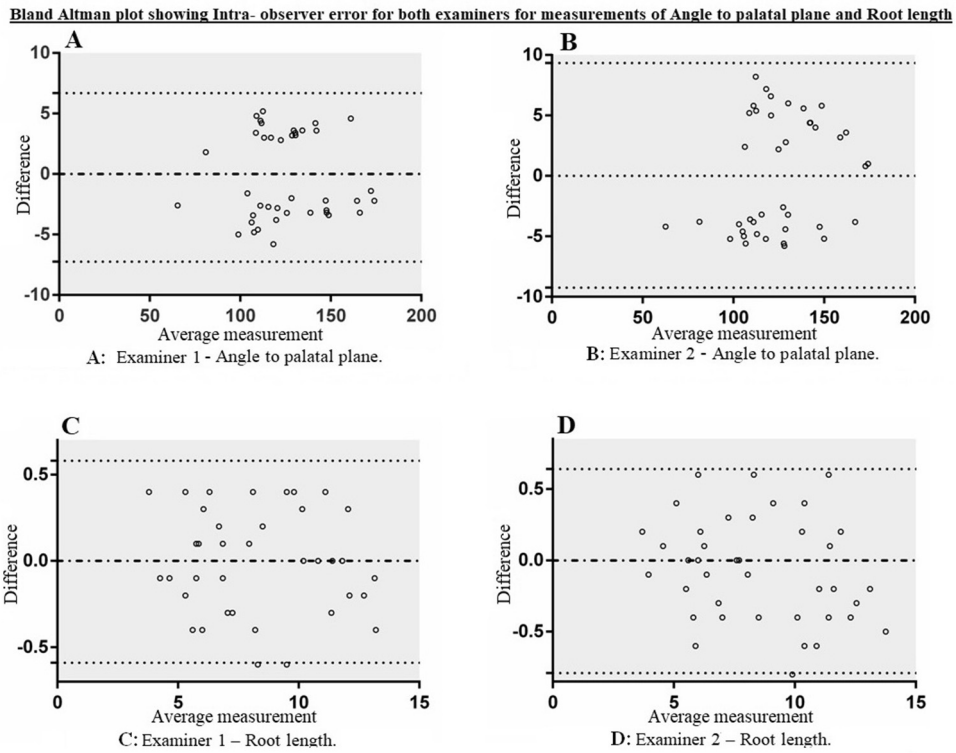

Fig 6. Bland-Altman plots showing intraobserver error for both examiners for measurements of angle to palatal plane and root length.

correlated with the distance to midline ($P = 0.01$) and moderately correlated with angle of the lateral incisor to the palatal plane ($P = 0.04$). In addition, angle of the lateral incisor to the palatal plane and crown distance were negatively correlated with each other ($P = 0.043$). Root length and crown distance were both found to be positively correlated with age on the unaffected side ($P < 0.05$) in contrast to the affected side, where no such correlation was found (Table VI).

DISCUSSION

In this study, mean root length of the maxillary lateral incisors on the impacted side was 1.21 mm shorter than

Table II. Bland-Altman limits of agreement for intraobserver error

	Examiner 1			Examiner 2		
Parameter	*Bias (mean difference)*	*SD of difference*	*95% limits of agreement*	*Bias (mean difference)*	*SD of difference*	*95% limits of agreement*
Angle to palatal plane	−0.27	3.55	(−7.24 to 6.69)	0.05	4.74	(−9.25 to 9.34)
Crown distance	−0.06	0.84	(−1.7 to 1.59)	0.12	0.69	(−1.23 to 1.48)
Root length	−0.01	0.3	(−0.59 to 0.58)	−0.07	0.36	(−0.79 to 0.64)
Angle to midsagittal plane	0.08	0.79	(−1.46 to 1.62)	0.07	0.72	(−1.35 to 1.49)
Distance to midline	0	0.26	(−0.2 to 0.5)	−0.04	0.33	(−0.68 to 0.6)

Table III. Descriptive statistics for linear and angular variables for 20 lateral incisors in the impacted group (I) and the normally erupted (N) group

Variable	*Minimum*	*Maximum*	*Range*	*Mean*	*SD*
Age	7.00	12.40	5.4	9.01	1.52
Angle to palatal plane: I	81.10	173.35	92.25	140.27	22.53
Angle to palatal plane: N	63.80	128.30	64.50	110.79	13.56
Crown distance: I	9.75	24.60	14.85	16.99	4.12
Crown distance: N	13.30	32.05	18.75	21.56	4.76
Root length: I	3.75	11.60	7.85	7.90	2.32
Root length: N	4.15	13.50	9.35	9.12	3.04
Angle to midline: I	−46.50	37.45	83.95	−4.31	21.27
Angle to midline: N	−24.80	65.10	89.90	25.97	22.38
Distance to midline: I	1.50	14.10	12.60	6.22	2.58
Distance to midline: N	4.8	12.25	7.45	7.56	1.92

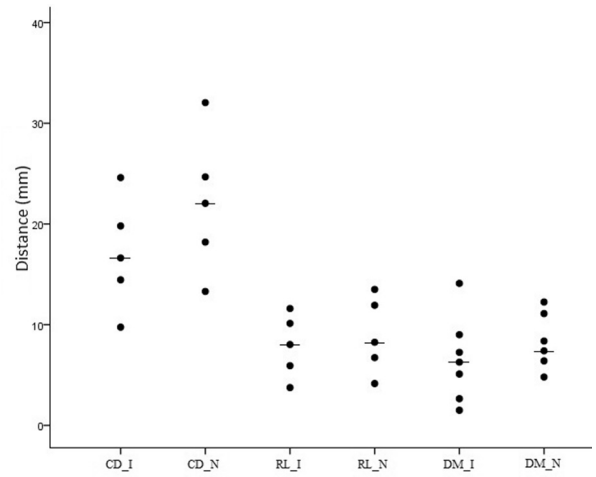

Fig 7. Scatter plot for distance of linear variables (mm) comparing the lateral incisor on the impacted side and that on the normally erupted side. *CD_I*, *CD_N*, distance of crown of lateral incisor to palatal plane on impacted side and normal side, respectively; *RL_I*, *RL_N*, root length of lateral incisor on impacted side and normal side, respectively; *DM_I*, *DM_N*, distance of lateral incisor to midline on impacted side and normal side, respectively.

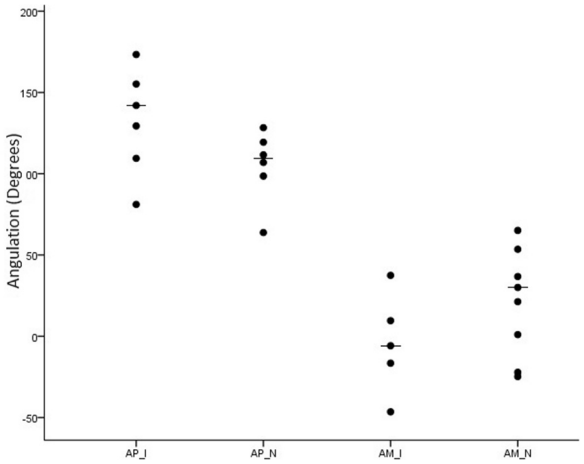

Fig 8. Scatter plot for angular variables (°) comparing the lateral incisor on the impacted side and that on the normally erupted side. *AP_I*, angle of lateral incisor to palatal plane on impacted side; *AP_N*, angle of lateral incisor to palatal plane on normally erupted side; *AM_I*, angle of long axis of lateral incisor to midsagittal plane on impacted side; *AM_N*, angle of long axis of lateral incisor to midsagittal plane on normally erupted side.

on the normal side ($P < 0.05$). In a study comparing lateral incisor root length in impacted maxillary canine subjects, Kim et al[9] concluded that the maxillary incisors on the affected side had shorter root lengths compared with the contralateral unaffected side. In similar studies, Becker et al[21] and Liuk et al[6] used conventional radiographs and 3-dimensional radiographs, respectively, to conclude that on average the length of lateral incisors adjacent to palatally displaced canines were 2.1 mm shorter than those adjacent to normal canines. The difference of 1.2 mm in mean length in our study demonstrated that the roots of lateral incisors adjacent to palatally impacted maxillary incisors also show discrepancy in root length compared with the normally erupted side. A strong correlation was further found between age and root length of the lateral incisor of the unaffected group,

Table IV. Results of Wilcoxon signed rank test comparing the variables between the lateral incisor on the palatally impacted maxillary incisor side (IG) and the control group (NG)

	IG (n = 21)		*NG (n = 21)*			
Variable	*Mean*	*SD*	*Mean*	*SD*	*Mean difference*	*P (t test)*
Angle to palatal plane	140.27	22.53	110.78	13.56	29.47 ± 18.37	<0.001†
Crown distance	16.99	4.12	21.56	4.76	−4.57 ± 4.69	<0.001†
Root length	7.92	2.32	9.11	3.04	−1.21 ± 1.73	0.006*
Angle to midsagittal plane	−4.31	4.76	25.97	5.00	−30.27 ± 27.26	<0.001†
Distance to midline	6.22	2.58	7.56	1.92	−1.34 ± 2.95	0.057

*Significant at the $P < 0.05$ level; †significant at the $P < 0.005$ level.

Table V. Correlation between lateral incisor variables on the palatally impacted maxillary central incisor side group

	Crown distance		*Root length*		*Angle midline*		*Distance midline*	
Variable	*Pearson correlation*	P	*Pearson correlation*	P	*Pearson correlation*	P	*Pearson correlation*	P
Ang. Palatal plane	−0.456	0.043*	0.025	0.917	−0.436	0.040*	−0.500	0.834
Crown distance			0.092	0.669	0.110	0.643	0.185	0.436
Root length					−0.229	0.330	−0.377	0.101
Ang. midline							0.560	0.010*

*Correlation is significant at the $P < 0.05$ level.

Table VI. Correlation of height and root length with age for lateral incisors on impacted side and normal side

	Age	
Variable	*Pearson correlation*	P *value*
CD_I	0.336	0.148
CD_N	0.600	0.005*
RL_I	0.307	0.189
RL_N	0.502	0.024*

CD_I, distance of crown of lateral incisor to palatal plane on impacted side; *CD_N*, distance of crown of lateral incisor to palatal plane on normal side; *RL_I*, length of lateral incisor root on impacted side; *RL_N*, length of lateral incisor root on normal side.
*Correlation is significant at the $P < 0.05$ level (2-tailed).

whereas no correlation was found respectively between age and root length of the incisor on the impacted side (Fig 10). With the mean age in our study being 9.01 years, an age at which lateral incisor roots are developing, the Wilcoxon signed rank test along with Pearson correlation with age indicate that the palatally impacted maxillary central incisor interfered with the normal pattern of root development of the adjacent lateral incisor. Early correction of the adjacent palatally located central incisor may dislodge it away from the lateral incisor roots, creating more space for normal root growth.

Jacobs concluded that palatally displaced canines exert a buccally directed force that causes the adjacent lateral incisor root to tip labially and its crown palatally.[7] Liuk et al[5] suggested that lateral incisors adjacent to palatally displaced canines will appear to be retroclined or more upright in the sagittal plane by 13.2°. However, the findings in studies carried out on palatally impacted canines contrast the results of our study, where it was found that palatally displaced maxillary central incisors induced more proclination of the adjacent lateral incisors in the sagittal plane by 29.47° ($P < 0.001$). This is corroborated by the fact that the change in orientation of the central incisor crown toward a palatal direction during the mixed dentition might result in impingement on the closely located root of the developing adjacent lateral incisor. The palatally and distally directed force from the central incisor crown causes the roots of the lateral incisor to tip distally and palatally, while the crown swings labially and mesially. This rotational movement causes the crown of the lateral incisor to be more proclined in the sagittal plane, accompanied by a more vertically located crown, as seen in Table IV. As might be expected, correlation exists between angle to palatal plane and crown distance ($P < 0.05$), as seen in Table V and Figure 9. Statistical analyses revealed that the crown of the lateral incisor on the affected side was located 4.57 mm ($P < 0.001$) closer to the palatal plane or higher than the lateral incisor crown on the normally erupted side. In addition, Pearson correlation revealed a significant correlation of age and crown distance on the unaffected side, whereas no correlation was found between age and crown distance of lateral incisor on the impacted side, further supporting the fact that normal eruption of the lateral

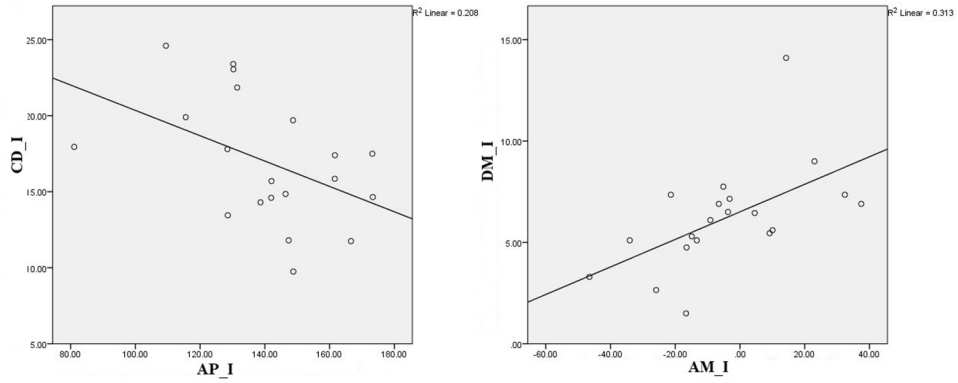

Fig 9. Scatter plot showing significant correlation between lateral incisor variables on the palatally impacted maxillary central incisor group. *CD_I*, distance of crown of lateral incisor to palatal plane on impacted side; *DM_I*, distance of lateral incisor to midline on impacted side; *AP_I*, angle of lateral incisor to palatal plane on impacted side; *AM_I*, angle of long axis of lateral incisor to midsagittal plane on impacted side.

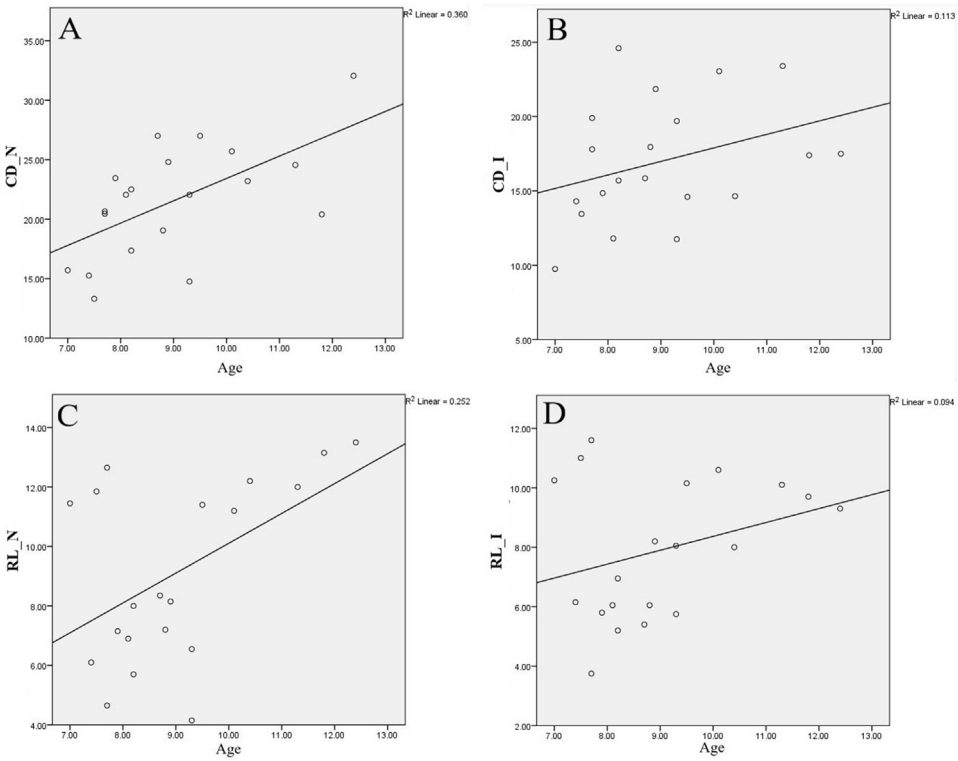

Fig 10. Scatter plot showing correlation of age with **A,** distance of crown of lateral incisor to palatal plane on unaffected side (CD_N), **B,** distance of crown of lateral incisor to palatal plane on impacted side (CD_I), **C,** length of lateral incisor root on unaffected side (RL_N), and **D,** length of lateral incisor root on impacted side (RL_I).

incisor is impaired by presence of the palatally impacted maxillary central incisor.

In a study carried out by Bonetti et al,[22] maxillary lateral incisors were found to have an increase in distal inclination after eruption until 10 years of age, remaining constant afterwards. In a similar study carried out by Liuk et al[5] of the association between palatally displaced canines and lateral incisors, there was an

increase in distal tipping of lateral incisors positioned adjacent to palatally displaced canines. These 2 studies prove that lateral incisors have a distal inclination in the mixed dentition, directing further away from the midline when palatally displaced canines are present. In our study, lateral incisors in the impacted group were found to be mesially inclined in the axial plane with a mean difference of 30.27° ($P < 0.001$) and were closer to the midline with a mean difference of 1.34 mm compared with the unaffected side. Distal tipping of the root combined with mesial tipping of the crown explains the tendency of inclination of the long axis of the lateral incisor toward the midline when seen in axial slices. Pearson correlation further revealed a strong correlation between angle and distance to midline ($P < 0.05$; Table V; Fig 9). Therefore, the slight discrepancy in distance to the midline between the lateral incisor of the impacted side and the contralateral side, when viewed in both the coronal and axial planes, can be explained as being a result of the inclination of the lateral incisor toward the midsagittal plane.

CONCLUSION

The normal orientation, position, and root development of lateral incisors were influenced by the presence of an adjacent palatally impacted maxillary central incisor.

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