



Original Article

Association Between Impacted Maxillary Canines and Adjacent Lateral Incisors: A Retrospective Study With Cone Beam Computed Tomography

Sevgi Koral^{ID}, Ayça Arman Özçırpıcı^{ID}, Nilüfer İrem Tunçer^{ID}

Department of Orthodontics, Başkent University, Faculty of Dentistry, Ankara, Turkey

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Main Points

- The maxillary lateral incisors play an important role on maxillary canine impaction.
- Smaller sized lateral incisors are significant etiologic factors of maxillary canine impaction.
- Angulation of the lateral incisor to midline and axis of the adjacent canine are defined as predictors of maxillary canine impaction.

ABSTRACT

Objective: The goal of this study was to evaluate the association between the morphologic characteristics of maxillary lateral incisors and maxillary canine impaction by using cone beam computed tomography (CBCT) images.

Methods: CBCT images of 52 patients (19 male and 33 female) with unilateral impacted maxillary canines were selected. The volume, root, and total lengths of the lateral incisor, mesiodistal and buccolingual widths of the lateral incisor crowns, angles between the central axis of the lateral incisor and the midline, occlusal plane, and the central axis of canines in both the impacted and non-impacted side were measured and compared.

Results: Statistically significant differences were obtained when comparing the volume of the lateral incisor, the mesiodistal and buccolingual widths of the lateral incisor crown, the root and total lengths of the lateral incisors, and angles between the central axis of the lateral incisor and the midline and the central axis of the adjacent canine ($P < .05$). There were no significant differences in lateral incisor axis and the maxillary occlusal plane angulation.

Conclusion: The association between the morphologic and angular features of the maxillary lateral incisors and maxillary canine impaction was confirmed. The volume of the lateral incisor, mesiodistal and buccolingual width of the lateral incisor crown, root and the total length of the lateral incisor, and the lateral incisor angulation to the midline and the axis of adjacent canine were found to be strong predictors of maxillary canine impaction.

Keywords: Maxillary canine impaction, lateral incisor length, lateral incisor width, lateral incisor volume, cone beam computed tomography

INTRODUCTION

Permanent maxillary canines are the most frequently impacted teeth with the exception of the third molars, with the prevalence of impaction of 1% to 5%.¹ Maxillary canine impaction is more frequently seen palatally and unilaterally. It also has higher incidence in females than in males.²

At the beginning of its eruption, the maxillary canine's tooth bud is located below the orbital floor and needs to descend 22 mm to reach its final occlusal position.² During the mixed dentition stage, the permanent maxillary canine is inclined mesially and positioned high along the distal side of the apical third of the maxillary

lateral incisor root, which acts as a guide along which the canine erupts while simultaneously uprighting its mesial inclination. Meanwhile, root development of the lateral incisors is close to completion at this stage. These teeth inherently affect the canines' eruption pathway, and anomalies in their size, shape, and number are considered to lay the foundations of one of the etiologic theories of maxillary canine impaction, especially of the palatal side. Therefore, the incidence of maxillary canine impaction would be relatively greater in patients with peg-shaped or missing maxillary lateral incisors, as the guiding function of the maxillary lateral incisors' root is lost.²⁻⁵

It is established that morphologic anomalies of the maxillary lateral incisors have a close association with maxillary canine impaction.⁶⁻⁸ Moreover, there is a significant decrease in the mesiodistal width of the maxillary teeth in patients with canine impaction.^{7,9} Supporting this theory, studies have been conducted to establish that maxillary canine impaction is associated with the morphology of the lateral incisor.⁷ Therefore, although the exact etiology of the impacted canines is not known, it seems that the adjacent lateral incisor plays a critical role, because the eruption of the maxillary canine and the adjacent lateral incisor's size and eruption are controlled by the same genes.¹⁰

Cone beam computed tomography (CBCT) is a radiographic technique which is used in dentistry, including orthodontics. High-quality diagnostic three-dimensional (3D) images presented by CBCT can be analyzed at any dimension. This makes angular, linear, and volumetric measurements more reproducible and accurate.^{11,12}

The rationale behind beginning our study was to determine the possibility of the maxillary canine impaction even on the 2D images, by detecting early determinants associated with the adjacent lateral incisors that are effective in maxillary canine impaction. The primary purpose of this study was to analyze and compare the morphologic characteristics of the maxillary lateral incisors on impacted and non-impacted sides in cases presenting unilateral maxillary canine impaction, by using 3D-reconstructed CBCT images. The secondary aim was to corroborate the association between the features of the maxillary lateral incisor and maxillary canine impaction.

METHODS

CBCT images of 52 patients (19 male and 33 female, average age of 20.8 years) presenting unilateral maxillary canine impaction were selected from the archives of dental faculties (Başkent University and Eskişehir Osmangazi University)

Table 1. Demographic characteristics of patients included in the study

Gender	N	Average Age	Age (Min-Max)
Woman	33	19.8 years	12.8-37.5
Man	19	22.7 years	12.5-36.2
Total	52	20.8 years	12.5-37.5

N, number; Min-Max, minimum and maximum values.

(Table 1). The patients had already given written informed consent to their clinics to use their personal data, and our University Institutional Review Board approved this study to use the universities' archives (Project no: Project no: D-KA 19/21).

Algerban et al.'s¹³ study was taken into consideration for power analysis. The sample size was determined by power analysis to detect statistical significance of 80% power and 5% error ratio with 0.4 effect size. The inclusion criteria were the unilateral impaction of maxillary permanent canines, both maxillary lateral incisors present and erupted, and no dentofacial deformities or systemic diseases.

In the study, 28 of the CBCT images were acquired with the Morita 3D Accuitomo 170 (J Morita, Kyoto, Japan) device (90 kV, 5 mA, 0.08, 0.125, 0.160, 0.200 mm voxel size and 100 × 50 FOV), and 24 of the CBCT images were obtained using a Promax 3D Mid (Planmeca, Helsinki, Finland) machine (94 kVp, 14 mA, 0.200 mm voxel size and 130 × 90 mm or 130 × 55 mm FOV).

All of the data sets were exported and converted using the Digital Imaging and Communications in Medicine format. Images were created and measurements were carried out using Dolphin Imaging & Management Solutions software program (Version 11.5 Premium, Patterson Dental, CA, USA) (Figure 1). To aid better visuals and avoid errors during the point selection, the enlarging, contrast, and brightness features of the software program were used. All data were measured in millimeter, cubic millimeter or angle, and the same experienced investigator made all landmark identifications and measurements to prevent inter-observer variability.

In this study, only patients with unilateral canine impaction either on the left or right sides were selected. Furthermore, morphological characteristics and angular features of the adjacent lateral incisor were measured to compare the impacted and non-impacted sides. For this purpose, the volume, root, and total lengths of the lateral incisor tooth, the mesiodistal and buccolingual widths of the lateral incisor crown, the angles between the central axis of the lateral incisor and the midline, the maxillary occlusal plane, and the central axis of canine were measured. The line passing through the crista galli and the anterior nasal spine was used as midline and the line passing through the

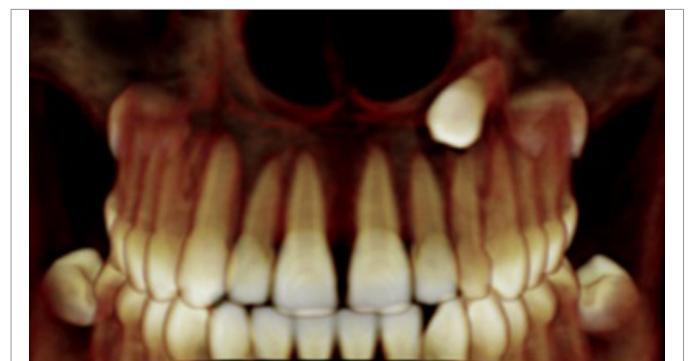


Figure 1. Volumetric rendered image with the surrounding structures.

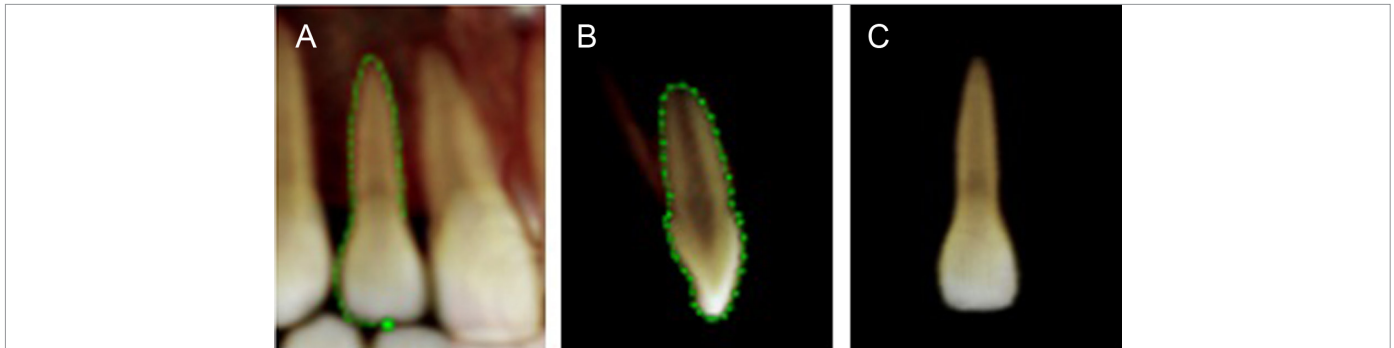


Figure 2. A-C. (A) Maxillary right lateral incisor's boundaries were drawn from the crown tip to the root apex on the coronal plane; (B) Drawing the lateral incisor's boundaries on the sagittal plane; (C) Maxillary right lateral incisor separated from the surrounding structures on 3D image using the Dolphin Imaging & Management Solutions software program.

mesio Buccal cusp of the maxillary first molar and incisal edge of the maxillary central incisor was used as maxillary occlusal plane.

Images were oriented on the lines of the anterior nasal spine and posterior nasal spine, and the midsagittal line was also determined before the measurements carried out. We determined the midsagittal plane through the crista galli, anterior nasal spine, and posterior nasal spine. In addition, we used reference planes while measuring the angles. The axial plane was through the anterior nasal spine and posterior nasal spine, and perpendicular to the sagittal plane. The coronal plane was determined through the anterior nasal spine and perpendicular to the sagittal and axial planes. The angle between the lateral incisor and occlusal plane was measured on the sagittal plane. The lateral incisor and canine angle and the lateral incisor and midline angle were measured on the frontal (coronal) plane.

For the volumetric measurements, Dolphin software offered the opportunity to draw the outer boundaries of the tooth on the volumetric rendered image with the "use volume sculpting" command. After drawing the boundaries of the lateral incisor, it could be separated from the surrounding structures by using the "cut" tool of the program. First, we drew the lateral incisor's boundaries from the crown tip to the apex tip by following the border of the tooth on the coronal plane, and separated it from surrounding structures by the "cut" tool (Figure 2A). Then, the same process was repeated on the other planes (Figure 2B). Finally, lateral incisor was separated from other structures in all planes, and the approximate volume of the tooth, which was

isolated, was measured by using the "volume" command. We could measure the approximate volume by using this procedure (Figure 2C).

The buccolingual and mesiodistal widths of the lateral incisor crowns were measured from the widest point of the crown perpendicular to the long axis on the sagittal and the coronal section, respectively (Figure 3A and B). The length of the root was measured from the lowest buccal cemento-enamel junction (CEJ) level to the root apex, and the total length of the lateral incisor was measured from the incisal tip to the root apex on the sagittal section (Figure 3C).

The angles between the axis of the lateral incisor and the midline (Figure 4A) and the axis of the canine were measured from the frontal view of the CBCT image (Figure 4B and 4C). From the sagittal view, the angle between the axis of the lateral incisor and maxillary occlusal plane was measured (Figure 5).

All of the parameters were reanalyzed by the same researcher 11 days after the last measurement, on 13 of the randomly selected CBCT images to assess intra-observer reliability using the intra-class correlation coefficient. The margin of error was statistically insignificant.

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics Version 17.0 software (IBM Corporation, Armonk, NY, USA). The normality of distributions was tested using the Shapiro-Wilk test.

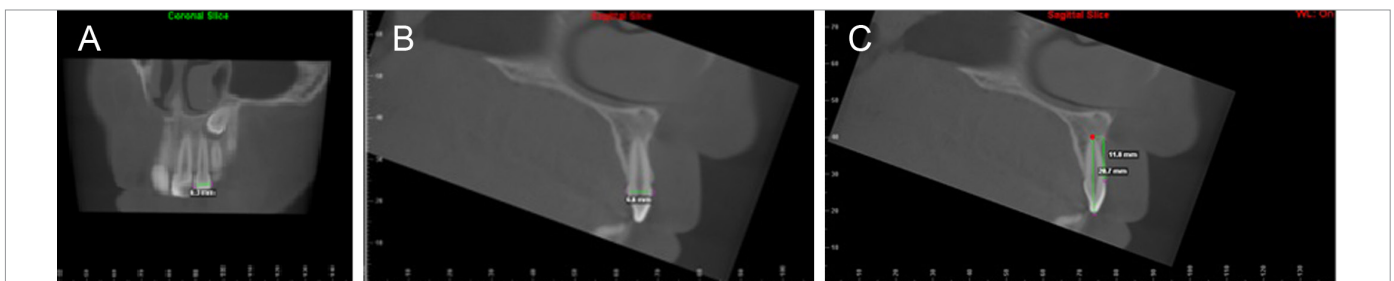


Figure 3. A-C. (A) Mesiodistal width of the crown measured from the widest point of the crown on the coronal section; (B) Buccolingual width of the crown measured from the widest point of the crown on the sagittal section; (C) Length of the root measured from the lowest buccal CEJ level to the root apex and total length of the lateral incisor measured from the incisal tip to the root apex on the sagittal section.

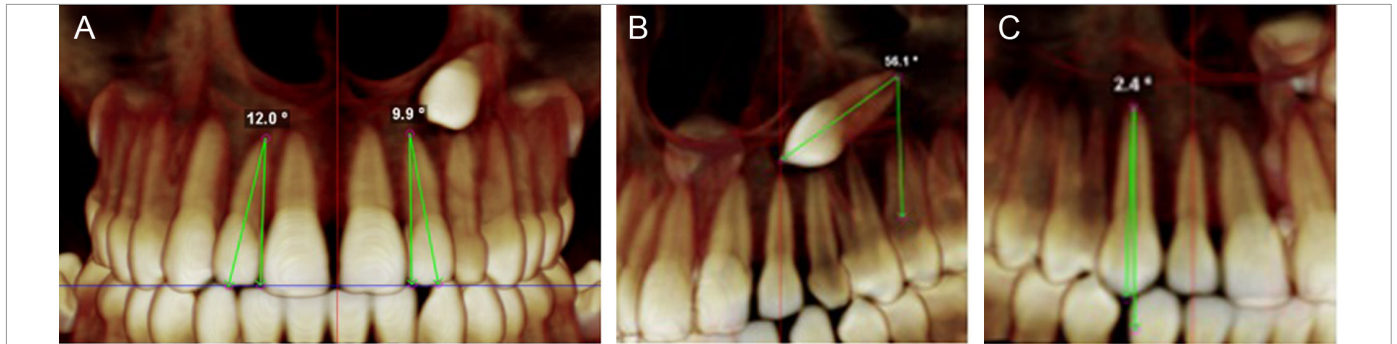


Figure 4. A-C. (A) The angle measured between the axis of the lateral incisor and the line parallel to midline; (B) The angle measured between the line parallel to axis of the lateral incisor and the axis of the canine on the left side; (C) The angle measured between the line parallel to axis of the lateral incisor and the axis of the canine on the right side.

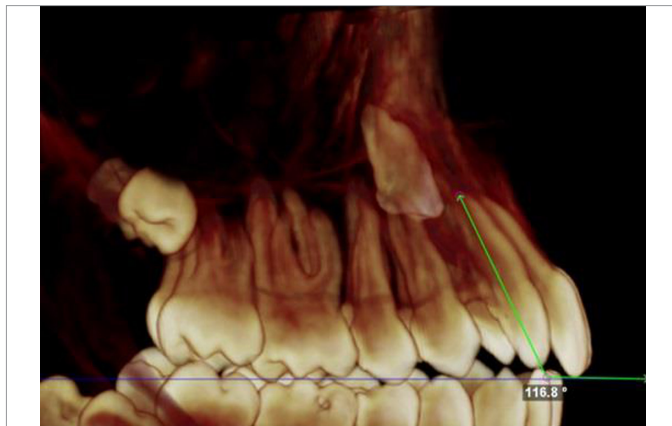


Figure 5. The angle measured between the axis of the lateral incisor and the line parallel to the maxillary occlusal plane.

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Descriptive statistics for continuous variables were expressed as mean ± SD and median (min-max). The differences in linear and angular measurements between impacted and non-impacted sides were evaluated using the paired *t*-test or the Wilcoxon Signed-Rank test, where appropriate. Intra-class correlation coefficients and 95% confidence intervals were also calculated for both linear and angular measurements to examine intra-observer agreement (reliability) levels (Table 2). A *P* value less than .05 was considered as statistically significant.

Measurements	Impacted Side	Non-impacted Side
U2 BL (mm)	0.897 (0.696-0.969)	0.902 (0.707-0.970)
U2 MD (mm)	0.970 (0.905-0.991)	0.836 (0.542-0.949)
U2tl (mm)	0.990 (0.966-0.997)	0.969 (0.899-0.991)
U2rl (mm)	0.990 (0.967-0.997)	0.976 (0.922-0.993)
U2v (mm ³)	0.994 (0.980-0.998)	0.994 (0.981-0.998)
U2^ML (°)	0.959 (0.870-0.988)	0.968 (0.897-0.991)
U3^U2 (°)	0.994 (0.981-0.998)	0.958 (0.868-0.988)
U2^MOP (°)	0.994 (0.981-0.998)	0.995 (0.985-0.999)

U2, maxillary lateral incisor; U3, maxillary canine.
BL, buccolingual width; MD, mesiodistal width; tl, total length; rl, root length; v, volume; ML, Midline; MOP, maxillary occlusal plane.

RESULTS

Intra-observer agreement levels were found to be clinically acceptable and highly reliable in terms of both linear and angular measurements, on both impacted and non-impacted sides (*P* < .001). Intra-observer agreement (reliability) levels ranged from 0.836 to 0.995.

Descriptive statistics and comparisons for the linear and angular measurements between the impacted and non-impacted sides are shown in Table 3.

The buccolingual and mesiodistal widths of the lateral incisor crown were significantly smaller on the impacted side than that on the non-impacted side (*P* < .05). The mean buccolingual width of the lateral incisor crown was 6.6 mm on the impacted side and 6.9 mm on the non-impacted side. The mean mesiodistal width of the lateral incisor crown was 6.6 mm on the impacted side and 6.9 on the non-impacted side.

There were significant differences in both the root length and total length of the maxillary lateral incisors between the 2 sides (*P* < .05). Root length of the lateral incisor on the impacted side (13.1 mm) was shorter compared to the non-impacted side (14 mm) (*P* < .05). Similarly, the total length of the lateral incisor on the impacted side was 21 mm, whereas it was 22 mm on the non-impacted side.

The mean maxillary lateral incisor volume was also significantly smaller (376 mm³) on the impacted side compared to the non-impacted side (400 mm³), by 31.4% (*P* < .05).

Significant differences were determined for the angular measurements between impacted and non-impacted sides (*P* < .001). Angulation between the maxillary lateral incisor axis and midline was higher for the non-impacted side, with a mean of 16.4°, compared with 11° for the impacted side.

There were no significant differences in the angulation between the lateral incisor axis and the maxillary occlusal plane (*P* > .05). The maxillary lateral incisors created an angle of 96.5° and 91.4° with the maxillary occlusal plane on the impacted and non-impacted sides, respectively.

Table 3. Comparison between impacted and non-impacted sides

Measurements	Impacted Side		Non-Impacted Side		P
	Mean ± SD	Median	Mean ± SD	Median	
U2 BL (mm)	6.68 ± 0.76	6.60	6.87 ± 0.63	6.90	.013 [†]
U2 MD (mm)	6.60 ± 0.82	6.60	6.77 ± 0.64	6.90	.026 [†]
U2tl (mm)	20.48 ± 2.71	20.80	21.57 ± 2.1	21.85	<.001 [†]
U2rl (mm)	12.89 ± 2.28	13.10	13.97 ± 1.8	14.05	<.001 [†]
U2v (mm ³)	382.68 ± 10	376.6	447.2 ± 153	400.0	<.001 [†]
U2^AML (°)	17.84 ± 7.50	16.40	12.54 ± 5.6	11.40	<.001 [†]
U2^MOP (°)	93.13 ± 21.65	96.45	92.32 ± 21	91.40	NS
U3^U2 (°)	58.28 ± 46.67	45.10	12.13 ± 31	4.35	<.001 [†]

[†]Wilcoxon's test; [†]Paired t-test.
NS, Not significant; SD, Standard deviation.

The angle between the maxillary lateral incisor and maxillary canine axis on the impacted side was higher than the non-impacted side ($P < .001$). The mean angles between the lateral axis and canine axis were 58.28° and 12.13° on the impacted and non-impacted sides, respectively.

DISCUSSION

In the current study, differences in the morphology and angular features of the maxillary lateral incisors were comparatively analyzed on 3D-reconstructed CBCT images between impacted and non-impacted sides, in cases presenting unilateral maxillary canine impaction. In order to make a reliable and reproducible comparison, we used CBCT images of unilateral impaction cases so that we could use the subjects as their own controls, and most importantly, eliminate inter-individual variability.¹⁴ Using CBCT images provided many advantages, a few of which are mentioned below. The information collected from 3D radiography was significantly higher than that from traditional periapical and panoramic images.^{15,16} CBCT provided extremely detailed 3D imaging and more beneficial views. Furthermore, superimpositions of images could be eliminated and the scanned anatomical structures, like the roots of teeth, could be reconstructed in different planes; this may enable the best treatment plan for the patient.¹⁷ It is reported that only severe resorptions of roots can be predicted with panoramic images.¹⁸ Therefore, the use of CBCT imaging may affect the absolute relevance of orthodontic treatment planning.

Patients were exposed to the high doses of radiation while obtaining medical CT scans. Although medical CT eliminates the disadvantages of 2D radiography, its clinical utility is limited because of the high radiation doses.¹² CBCT has an advantageous application in dentistry because it utilizes considerably lower radiation doses than medical CT.

Our findings demonstrated that all of the morphologic and angular characteristics of the lateral incisors, except for the angulation of the lateral incisor axis and the maxillary occlusal plane, were

significantly different between the impacted and non-impacted sides. Currently, the 2 most popular theories reported in the literature are the lack of guidance (peg-shaped or missing),^{19,20} and the genetic theory,^{2,9} which both share the opinion that certain genetic characteristics associate with the impaction of the maxillary canine. Of the mechanisms proposed, the guidance theory has been observed as the most acceptable explanation, which proposes that the root of the maxillary lateral incisor has a critical role in the eruption of the maxillary canine. According to guidance theory, maxillary canine eruption would deviate if the maxillary lateral incisor's root function were impaired, indicating that it plays a key role in the normal eruption of the maxillary canine. Numerous researches in the literature have shown that anomalies in the maxillary lateral incisors have a significant association with maxillary canine impaction.^{2,6,21} Moreover, an important decrease in the mesiodistal width of the maxillary teeth, including the maxillary incisors, had also been demonstrated in patients with maxillary canine impaction.^{7,9}

On average, root length and total length of the lateral incisors adjacent to the impacted canines were smaller by 1.5 mm when compared to those on the non-impacted side. These findings are also in accordance with previous studies on lateral incisor lengths being shorter on the impacted side.²²⁻²⁴ There was also a significant difference in the crown widths and volume of the lateral incisor between the 2 sides. These findings corroborate the previous findings on lateral incisor volume being smaller on the impacted side.^{17,22,23} On the other hand, Kim et al.²⁴ did not find significant differences in any of the parameters regarding the crown of the maxillary lateral incisor.

The results of this study seem to indicate that shorter lengths and reduced volume of the maxillary lateral incisors affects impacted maxillary canines, as it can utilize a dominant local influence. According to guidance theory, these results can prove that smaller maxillary lateral incisors result in impaired eruption of the maxillary canine. It can be interpreted that patients with smaller crowns, roots, and reduced volumes of the maxillary lateral incisor are vulnerable to deviated eruption of the maxillary canine.

The present findings revealed significant differences between maxillary lateral incisors adjacent to impacted and non-impacted canines, in angulation with the adjacent maxillary canine and the midline. The midline angulation of the lateral incisor on the impacted side was lower than the on the non-impacted side, while Crincoli et al.²⁵ did not find a significant difference in lateral incisor axis and midline angulation between impacted and non-impacted sides. The explanation for our results can be that due to the maxillary impacted canine position, the axis of the adjacent lateral incisor might tend toward the midline and the lateral incisor adjacent to the impacted canine creates a narrower angle between the midline than the lateral incisor on the non-impacted side. Moreover, on the impacted side, the lateral incisor–canine axis angulation was significantly higher than that on the non-impacted side. Deckel et al.⁸ found significant differences in mesiobuccal rotation and palatal root torque of lateral incisors between the impacted and non-impacted canine sides. When the maxillary canine fails to erupt, its axis might tend mesially or distally, and in both of these conditions, the lateral incisors on the impacted side compose a wider angle with the canine axis. Alqerban et al.¹³ suggested that the angle between the impacted canine and the lateral incisor is a significant predictor of canine impaction. In mixed dentition, measurements of angle between the impacted canine and the teeth adjacent to canine using 3D images may prevent the resorption in adjacent teeth like lateral incisors. There are no significant differences between the 2 sides for the angulation of the lateral incisor axis and the maxillary occlusal plane.

In this study, the radiographic parameters of impacted maxillary canines associated with the adjacent lateral incisors were examined. The etiologic factors, such as the morphological and angular characteristics of lateral incisors, can be detected even at an early stage. Therefore, the present results may help orthodontists in the diagnosis, prevention, and planning of treatments for maxillary impacted canine.

The gubernacular canals that are thought to guide or direct the course of the erupting tooth may also be factors related impaction of teeth. Lower detection rates of gubernacular canals were observed in the maxillary lateral incisors, mandibular second premolars, and maxillary canines, and this could have resulted from the higher rate of accompanying eruption disturbances.²⁶ Therefore, in future studies, evaluation of the gubernacular canals and impaction of maxillary canines on CBCT images may also help predict the possible impaction of the maxillary canines.

This study was carried out in a retrospective design, which could be a limitation of this study. We would have preferred higher sample sizes. However, it was not possible to obtain more CBCT images because of the retrospective study design. Further studies are essential to evaluate angular and linear measurements within a larger sample size with CBCT images.

CONCLUSION

There are differences in lateral morphology and angular features between the impacted and non-impacted sides. The

volume of the lateral incisor, mesiodistal and buccolingual widths of the lateral incisor crown, root and the total length of the lateral incisor, lateral incisor angulation to the midline and the adjacent canine, were strong predictors based on CBCT radiographs, and may assist orthodontists to identify the possibility of impaction.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Başkent University (approval No: D-KA 19/21).

Informed Consent: Verbal informed consent was obtained from all participants who participated in this study.

Peer Review: Externally peer-reviewed.

Author Contributions: Concept - S.K., A.A.Ö., N.İ.T.; Design - S.K., A.A.Ö., N.İ.T.; Supervision - A.A.Ö., N.İ.T.; Materials - S.K.; Data Collection and Processing - S.K.; Analysis and Interpretation - S.K.; Literature Review - S.K.; Writing - S.K.; Critical Review - S.K., A.A.Ö., N.İ.T.

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