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Evaluation of the Relationship Between the Maxillary Sinus and Nasopalatine Canal of Maxillary Impacted Canines by Cone Beam Computed Tomography

Filiz Aydogan Akgun[1*], Melike Yurttas[2]

Abstract

Introduction. One of the critical parameters evaluated while planning orthodontic treatment for impacted canines in clinical practice is the relationship between impacted canines and adjacent anatomical structures. The nasopalatine canal (NPC) and maxillary sinus are anatomical formations that may be in close proximity to impacted canines.

This study **aimed** to determine the relationship between palatally impacted canines, the maxillary sinus, and the NPC.

Methods. A total of 105 impacted canines from 93 patients were evaluated using cone beam computed tomography (CBCT) images. The relationship between the impacted canine teeth, maxillary sinus, and NPC was assessed inside, outside, and at the border of the maxillary sinus floor and NPC walls. The millimetric distance between the impacted canine teeth and the borders of the maxillary sinus, the NPC, and the cortical bone of the palate was measured. Additionally, NPC morphology was assessed on the axial and sagittal CBCT images.

Results. Of all the impacted teeth, 47.6% (3.8% inside, 43.8% at the border) were associated with the sinus, while 42.8% (15.2% inside, 27.6% at the border) were associated with the NPC. A significant moderate negative correlation (-0.32) was observed between age and the distance between impacted left canine teeth and the cortical bone of the palate. Additionally, when a Y-shaped NPC was present, the impacted canines were predominantly situated outside the canal.

Conclusions. In this study, nearly half of the canines were located inside or at the border of the maxillary sinus and the NPC. Therefore, clinicians should carefully evaluate the relationship of impacted teeth with the maxillary sinus and the NPC during both orthodontic treatment and the extraction of impacted teeth.

Keywords
Impacted Canine; Cone Beam Computed Tomography; Nasopalatine Canal; Maxillary Sinus

[1] *Isparta Agiz ve Dis Sagligi Merkezi, Isparta, Turkey*
[2] *Deparment of Oral and Maxillofacial Radiology, Faculty of Dentistry, Kutahya Health Sciences University, Kutahya, Turkey*
*__Corresponding author__: filizydgn03@gmail.com

Introduction

Canine teeth are important in terms of dental aesthetics, function, and arch development due to their location and anatomy. The incidence of impacted maxillary canines differs between studies and countries, ranging from 0.8% to 8.4% [1, 2]. In the Turkish population, the incidence is approximately 3% [3, 4]. Unilateral impaction of maxillary canines is more common than bilateral impaction, with palatal impaction being more frequent than buccal impaction [2, 3]. The prevalence of maxillary canine impaction is greater among females compared to males [2, 3]. The side of impacted canines (right or left) varies across studies [2, 3]. While not highly prevalent, maxillary canine impaction can lead to alterations such as cyst formation, adjacent teeth resorption, distortion of arch dynamics, and ankylosis. Managing such cases necessitates a multidisciplinary treatment approach [3]. The treatment approach

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may vary depending on the position of the impacted canine tooth and its relationship with adjacent teeth and anatomical structures. Treatment options include orthodontic traction, extraction, autotransplantation, or monitoring without intervention.

The maxillary sinus, the largest paranasal sinus, is located bilaterally within the maxilla [5–7]. This horizontal pyramid-shaped sinus extends from the top to the base, reaching towards the zygomatic projection and nasal cavity. Its dimensions may vary depending on age and sex [8]. The maxillary sinus serves several important functions, including humidifying and warming aspirated air, increasing the surface area of the olfactory mucosa, balancing external and internal atmospheric pressure, contributing to voice resonance, reducing the weight of the craniofacial complex, influencing facial growth and development, directing secretions to the ostium through mucociliary movement, and producing nitric oxide [7, 9]. The lower wall of the maxillary sinus is formed by the alveolar process of the maxilla; in some cases, the roots of canine teeth may be in contact with the maxillary sinus [10]. Furthermore, when impacted, canine teeth may exhibit a closer relationship with the maxillary sinus [11]. This scenario potentially poses risks such as oroantral perforation, nerve damage during surgical procedures, root resorption, and prolonged duration of orthodontic treatment.

The nasopalatine canal (NPC), also known as the incisive canal, is a bony tunnel situated in the anterior midline of the palate, connecting the nasal and oral cavities [12]. Within this canal, the nasopalatine (incisive) nerve and artery reside, forming an anastomosis between the sphenopalatine nerves and arteries, as well as the greater palatine nerves and arteries. The oral opening of the NPC at the midline of the anterior palate is referred to as the incisive foramen, typically positioned just below the incisive papilla [13]. Anatomical variations in the NPC, including its shape, length, location, and incisive foramen diameter, the number of openings in the nasal fossa, and other morphological changes have been extensively evaluated in the literature [14–16]. However, studies evaluating the relationship between impacted canine teeth and the NPC, as well as the maxillary sinus are limited [11]. The relationship between the impacted canine tooth and the maxillary sinus/NPC should be carefully evaluated during orthodontic traction or tooth extraction procedures to prevent any complications [17]. The relationship between the impacted canine tooth and the mentioned anatomical structures should be determined with respect to factors such as the duration of orthodontic tooth movement, difficulty in extraction, and potential complications [18].

This study **aimed** to evaluate the relationship between palatally impacted maxillary canines, the maxillary sinus, the NPC, and the cortical bone of the palate using cone beam computed tomography (CBCT).

Materials and Methods

Study Design

This retrospective study was conducted at the Oral and Maxillofacial Radiology Clinic of the Faculty of Dentistry, Kutahya Health Sciences University, Kutahya, Turkey.

Study Sample and Eligibility Criteria

The inclusion criteria were as follows: (1) participants with both dental and chronological ages of 13 years or older; (2) no prior orthodontic treatment; and (3) absence of any pathology and anomaly in the maxillofacial region. The exclusion criteria were defined as follows: (1) any artifact or deficiency in the examination area and (2) a history of dental trauma or surgical procedures in the maxillofacial region.

CBCT images of 93 patients with palatally impacted maxillary canines were included in this study. A total of 105 palatally impacted canine teeth were evaluated.

Image Evaluation

All CBCT images were obtained using an Orthopantomograph OP 300 (Instrumentarium Dental, Tuusula, Finland) device, with standardized parameters, including a field of view 80 $\times$ 150 mm^2, 90 kV, 4 mA, and a voxel size of 350 μm. Measurements were conducted using OnDemand 3D Dental software (OnDemand3D Technology Inc., USA) by the same researcher (M.Y.), who has extensive experience in evaluating CBCT images. The relationships (inside, outside, and at the border) between the canine root apices and the maxillary sinus (Fig. 1), as well as between the canine crown tips and the NPC (Fig. 2) were examined. Perpendicular distances from the canine crown tip to the cortical bone of the palate and the lateral border of the NPC, as well as from the canine apex to the mesial border of the maxillary sinus, were measured on the axial CBCT images (Fig. 3). Additionally, NPC morphology was evaluated based on the coronal (a single canal, two separate canals, and Y-shaped canals [15]) and sagittal (cylindrical, funnel-shaped, spindle-shaped, and hourglass-shaped [19]) images.

Figure 1. Relationship between the maxillary sinus and impacted canines: inside (A – right canine), outside (B – right and left canines), and at the border (C – right canine).

Figure 2. Relationship between the nasopalatine canal and impacted canines: inside (A), outside (B) and at the border (C).

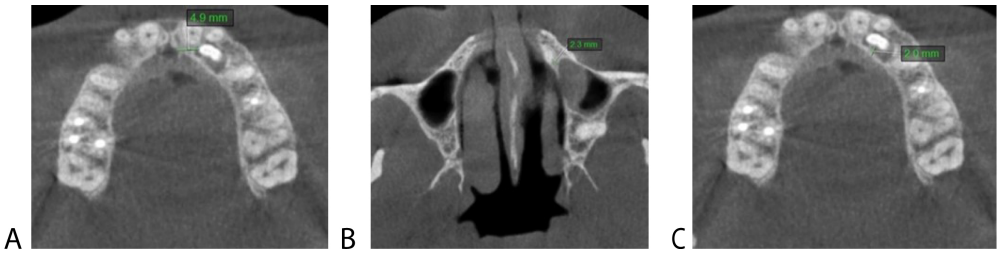

Figure 3. The distance from the canine apices to the lateral border of the nasopalatine canal (A); the distance from the canine apices to the mesial border of the maxillary sinus (B); the shortest distance from the canine crown to the cortical bone of the palate (C).

Statistical Analysis

Based on the statistical power analysis, considering the ratios with 95% power (at a significance level of 0.05), a minimum of 81 observations were required. As the first step of the statistical analysis, the assumption of normal distribution was made with the Shapiro-Wilk test, and the homogeneity of variance was checked with the Levene's test. The independent-sample t-test was used to compare the means of two independent groups with normal distribution. The Mann-Whitney U test was conducted to compare the means of independent groups with non-normal distribution. The relationship between continuous variables was determined using the Spearman's correlation coefficient. Fisher's exact test was used to test the relationship between categorical variables, depending on the sample size. P-values less than 0.05 were accepted as significant.

Results

A total of 105 impacted canine teeth, including 12 cases of bilateral impaction, were evaluated in this study. The descriptive statistics of all patients are presented in Table 1.

No differences were found in the relationship of the impacted canines with the sinus (inside, outside, and at the border) in terms of gender, irrespective of whether the impacted tooth was located on the right or left side ($p > 0.05$) (Table 2). The study revealed that the distances between the impacted canine teeth and the maxillary sinus, the cortical bone of the palate, and NPC were not affected by the patients' sex ($p > 0.05$). No differences in age were identified concerning the relationship between the impacted

Table 1. Descriptive parameters of enrolled cases.

Parameter		n	%
Side	Right	54	51.4
	Left	51	48.6
Sex	Female	85	81.0
	Male	20	19.0
IC relationship with the maxillary sinus	Inside	4	3.8
	Outside	55	52.4
	Border	46	43.8
IC relationship with the NPC	Inside	16	15.2
	Outside	60	57.2
	Border	29	27.6
NPC shape in the sagittal plane	Hourglass-shaped	10	9.5
	Spindle-shaped	11	10.5
	Funnel-shaped	33	31.4
	Cylindrical	51	48.6
NPC shape in the coronal plane	Y-shaped	41	39.0
	Single	60	57.2
	Double	4	3.8

Table 1 (Continued).

Parameter	n	Min	Max	Mean	Standard Deviation	Median
Age	105	14	77	40.14	15.22	38.0
Distance between IC and the maxillary sinus	105	0	15	2.75	3.60	1.80
Distance between IC and the NPC	104	0	11.8	2.86	2.62	2.55
Distance between IC and the cortical bone of the palate	105	0	4.2	0.71	0.79	0.60

Notes: IC – impacted canine; NPC – nasopalatine canal.

Table 2. Cross-sectional table of the sex-specific relationship of the impacted canines with the maxillary sinus (inside, outside, and at the border).

Relationship		Right Canine			Left Canine			All Canines		
		Female	Male	p*	Female	Male	p*	Female	Male	p*
Inside	n	2	0		2	0		4	0	
	%	4.7	0		4.8	0		4.7	0	
Outside	n	24	6	0.99	18	7	0.20	42	13	0.43
	%	55.8	54.5		42.8	77.8		49.4	65.0	
Border	n	17	5		22	2		39	7	
	%	39.5	45.5		52.4	22.2		45.9	35.0	

Notes: * – Fisher's exact tests.

canines and the sinus (inside, outside, and at the border), irrespective of whether the impacted tooth was located on the right or left side ($p > 0.05$) (Table 3). A significant moderate negative correlation (-0.32, $p < 0.05$) was observed between age and the distance between impacted left canine teeth and the cortical bone of the palate. In addition to the aforementioned results, no significant correlations were detected between anatomical measurements (distances) and age.

Significant associations were found only between the shape of the NPC in the coronal plane and right impacted canines (Table 4).

No statistically significant correlation was found between the distances from the impacted canines to the cortical bone of the palate, regardless of whether the impacted teeth were located on the right or left side ($p > 0.05$). Furthermore, a statistically significant interaction was observed between the relationships of the impacted canine teeth with the sinus and the NPC ($p < 0.05$) (Table 5). In cases where the impacted canine tooth was located inside the maxillary sinus, it was determined whether it was situated inside or at the border of the NPC. Additionally, in cases where the impacted canine tooth was located outside or at the border of the maxillary sinus, it was typically found to be outside the NPC.

Discussion

Considering their unique anatomical structure and positioning, canine teeth serve as a cornerstone for supporting orofacial aesthetics, functional occlusion, and dentoalveolar development. When choosing treatment options for impacted maxillary canines, it is noteworthy that these teeth are the second most frequently impacted teeth after wisdom teeth [20]. Hence, their position, anatomy, and relationship with neighboring anatomical structures are decisive [3]. Carefully assessing the relationship between the impacted canine tooth and the maxillary sinus and/or NPC, which are important anatomical structures in the upper jaw, is necessary because of the possible risk of oroantral perforation, nerve damage during surgical procedures, root resorption, and prolonged duration of orthodontic treatment [18, 21, 22]. The shortest distance from the cortical bone of the palate to the canine crown tip holds significance for both orthodontic treatment and extraction procedures, as it may affect post-treatment morbidity and treatment

Table 3. Cross-sectional table of the age-specific relationship of the impacted canines with the sinus (inside, outside, and at the border).

	Relationship	n	Patient's Age			
			Mean	Standard deviation	Median	p
Right canine	Outside	30	40.57	13.81	38.5	0.82*
	Inside and at the border**	24	39.67	15.65	38.0	
Left canine	Outside	25	43.64	15.55	40.0	0.13#
	Inside and at the border**	26	36.73	16.14	37.5	
Total (all canines)	Inside	4	52.00	21.73	59.0	0.13*
	Outside	55	41.96	14.57	39.0	
	At the border	46	36.93	14.91	38.0	

Notes: * – Independent-samples t-test. # – Mann-Whitney U test. ** – Due to the small number of cases where impacted canine teeth were inside the sinus, the cases where canine teeth were at the border of the sinus were analyzed together.

Table 4. Cross-sectional table of the relationship between the impacted canines and the nasopalatine canal in the sagittal and coronal sections.

			Right Canine – NPC				Left Canine – NPC			
			Inside	Outside	Border	p*	Inside	Outside	Border	p*
NPC shape in the sagittal plane	Hourglass-shaped	n	1	2	3	0.66	1	1	2	0.52
		%	10	7.4	17.6		16.7	3.0	16.7	
	Spindle-shaped	n	2	4	1		0	3	1	
		%	20	14.8	5.9		0	9.1	8.3	
	Funnel-shaped	n	3	8	8		1	9	4	
		%	30	29.6	47.1		16.7	27.3	33.3	
	Cylindrical	n	4	13	5		4	20	5	
		%	40	48.2	29.4		66.6	60.6	41.7	
NPC shape in the coronal plane	Y-shaped	n	1	14	8	0.03	1	15	2	0.22
		%	10	51.9	47.1		16.7	45.5	16.7	
	Single	n	9	13	7		5	16	10	
		%	90	48.1	41.1		83.3	48.5	83.3	
	Double	n	0	0	2		0	2	0	
		%	0	0	11.8		0	6	0	

Notes: * – Fisher's exact tests. NPC – nasopalatine canal.

Table 5. Cross-sectional table of the relationship between groups of impacted canines with maxillary sinus and impacted canines with the nasopalatine canal.

IC – NPC		IC–Maxillary sinus			p
		Inside	Outside	Border	
Inside	n	2	7	7	0.04*
	%	50	12.7	15.2	
Outside	n	0	30	30	
	%	0	54.5	65.2	
Border	n	2	18	9	
	%	50	32.7	19.6	

Notes: * – Fisher's exact tests. IC — impacted canine. NPC — nasopalatine canal.

prognosis. Therefore, this study examined the relationship between impacted maxillary canines with the aforementioned anatomical structures. Additionally, we investigated whether the shape of the NPC, which exhibits various variations, was affected by the presence of impacted canine teeth.

Individuals aged 13 years and above were included in this study because significant growth in the maxillary sinus typically ceases after the age of 12 years [23], and the maxillary canine teeth are expected to erupt around the age of 13 years [24]. Among the parameters evaluated in this study, only the nearest distance from the impacted canine to the cortical bone of the palate decreased with age; no other parameters were statistically affected by age. The decrease in the distance between the outer cortical bone and the impacted canine might be due to aging-related bone resorption or tooth eruption. In contrast to the findings of this study, Ok *et al.* [25] reported that the distance between the sinus and maxillary posterior teeth was affected by age. The present study examined the relationship between the sinus and canine, and the difference may have arisen from variations among individuals within the sample group [25]. To the best of our knowledge, no study evaluated the distance of the impacted canine from the NPC and/or the nearest cortical bone according to age.

The impacted canine teeth evaluated in this study were predominantly unilateral and observed in female patients, which was in line with previously published findings [2, 3]. None of the parameters evaluated in our study were affected by the patients' sex. Similar to our findings, Gu *et al.* [26] reported that the relationship between the sinus and posterior teeth was not affected by sex. On the contrary, Ok *et al.* [25] reported that root penetration was more common in men than in women.

Of all the impacted teeth, 47.6% (3.8% inside, 43.8% at the border) were associated with the sinus, while 42.8% (15.2% inside, 27.6% at the border) were associated with the NPC. These rates, which were higher than those reported by Köse *et al.* [11], may be attributed to differences in the sample group. The relationship between impacted teeth and the cortical bone surfaces of the sinus holds clinical significance in orthodontic treatment. These teeth may undergo root resorption, and in cases where extraction is necessary, sinus perforation may occur. Similarly, nerve damage may occur when extracting an impacted canine associated with the NPC.

The presence of a Y-shaped NPC in the coronal sections indicated that the impacted canine teeth, regardless of laterality (right or left), were mostly located outside the canal. This phenomenon may be attributed to the narrowing of the diameter of the Y-shaped canal toward the intraoral opening of the mouth, leading to an increase in the distance between the canine and the canal. In this study, the distribution of NPC shapes was ordered from most to least prevalent as single, Y-shaped, and double channel, similar to the findings of Bornstein *et al.* [27].

No statistically significant correlation was found between the relationship of the impacted canine teeth with the maxillary sinus (inside, outside, and at the border) and the distance from the impacted canine to the cortical bone of the palate. Depending on the position of impacted teeth, even if the impacted canine was far from the sinus, it could not be deduced that the canine was close to the cortical

bone. These results might be related to the depth and angulations of the impacted canine teeth.

Regardless of laterality, when the impacted canine teeth were located inside the NPC, they were found to be located either inside or at the border of the maxillary sinus ($p < 0.05$). This observation may be attributed to the angulation of the impacted teeth. For example, deeply and horizontally impacted canine teeth may extend toward both the maxillary sinus and the NPC.

Limitations

In this study, the missing and/or extracted adjacent teeth were not considered when evaluating the relationship of the impacted canine with the surrounding anatomical structures. Another limitation of this study is that the sample size, as well as the depth and angulation of the impacted canine, were not analyzed.

Ethical Statement

All procedures of this study were performed in accordance with the guidelines outlined in the Declaration of Helsinki. The study received approval from the Noninvasive Ethics Department of the Kutahya Health Sciences University (Decision Number: 2022/12-21).

Informed Consent

Informed consent forms were obtained from all patients and, for those under 18 years old - from their parents or legal guardians.

Data Availability

All data used in this study were incorporated into the manuscript, tables, and figures. There are no additional data or supplementary materials.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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