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Prevalence and Predictors of Root Resorption Associated with Maxillary Canine Impaction in an Orthodontic Tunisian Population: An Analytical Cross-Sectional Study

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Abstract

The main objective of this study was to determine the occurrence of root resorption of adjacent permanent teeth associated with impacted maxillary canines and to identify a predictive model for RR by means of orthopantomographic variables, with the intention of reducing the need for additional cone beam computed tomography (CBCT) imaging. ***Materials and Methods***: The sample consisted of 70 consecutive patients (43 females and 27 males, with a mean age of 17.03 years). A total of 90 impacted maxillary canines and adjacent teeth were analyzed using panoramic and CBCT radiographs. Univariable and multivariable analyses were respectively evaluated using chi-square test, Student's t-test, and binary logistic regression analysis. ***Results***: The prevalence of root resorption of the permanent teeth adjacent to the impacted canine was more frequent in females than in males (ratio 1.8), but without significant association. No relationship was found between the sex, the type, the side, and the buccopalatal position of the impacted canine and root resorption. A statistically significant relationship was noted between the canines located mesial to the midline of the lateral incisor and root resorption on the maxillary incisors. Therefore, adjacent root resorption caused by impacted maxillary canines can be affirmed to exhibit a greater amount of resorption as the position proximity of the canine crown and lateral incisor root increases. In this prediction model, the patient's age, the mesio-distal position, and the inclination of the impacted canine were the strongest predictors for RR. ***Conclusion***: The final prediction model for RR based on the available panoramic radiographs could be a helpful tool in justifying the need of additional CBCT examination.

Keywords: Maxillary impacted canines, Root resorption, Lateral incisor, Cone Beam Computed Tomography, Prediction model.

INTRODUCTION

The inclusion of the maxillary canine is a common eruption anomalies. Following the mandibular third molar, this tooth is the most frequently impacted, with a prevalence ranging from 1.7 to 5.4% in the general population and varying among different populations [1]. The lack of control and delay in management can lead to various complications such as displacement of adjacent incisors, formation of follicular cysts, ankylosis of the canine, resorption of adjacent tooth roots, shortening of the dental arch, and/or combinations of these complications. Root resorption of adjacent permanent teeth is one of the most significant and common complications [3-5].

Appropriate diagnosis, precise predictive analysis, and early intervention can potentially prevent these adverse effects. The exact etiology of root resorption associated with impacted maxillary canines is unknown. Several etiological factors have been considered, including pressure from the erupting canine, follicular activity, orthodontic forces, genetics, trauma, inadequate development of immature roots, and their susceptibility to resorption enzymes. Several studies have evaluated the prevalence, localization, and severity of maxillary canine impaction and root resorption worldwide, across various regions and ethnic populations [6].

To our knowledge, no study has been conducted to identify the prevalence and severity of root resorption associated with impacted maxillary canines in the Tunisian population. Therefore, this retrospective study aims to identify the prevalence of root resorption in adjacent permanent teeth associated with impacted maxillary canines, evaluate its severity using cone-beam computed tomography (CBCT) in a sample of the Tunisian population, highlight risk factors for root resorption, and develop a mathematical prediction formula for root resorption caused by impacted canines, based on parameters assessed from 2D panoramic radiographs, to anticipate root resorption diagnosis and appropriately time intervention.

MATERIALS AND METHODS

This is a retrospective analytical study conducted on patients who visited the dento-facial orthopedics department at the Farhat Hached University Hospital in Sousse.

Seventy Tunisian patients with ninety impacted canine were included.

The inclusion criteria were the following:

- Tunisian patients, both male and female, aged at least 12 years.
- Inclusion of maxillary canines only, unilateral or bilateral.
- Good general health condition.
- Panoramic radiograph performed.
- Indication for and completion of a CBCT scan.

The exclusion criteria were the following:

- Patients who have had or are undergoing orthodontic or orthopedic treatment.
- Age < 12 years.
- Systemic or syndromic pathologies.
- Another impacted tooth in the maxillary and/or mandibular arch.
- Secondary resorption due to trauma or pulpal pathologies.

All panoramic radiographs are analyzed on a conventional lightbox by the same examiner. CBCT scans were analyzed using DICOM software.

Method of measurement:

The following measurements were performed for every maxillary displaced canine:

1. Age
2. Gender
3. Canine-related variables:

- Type of displacement: unilateral or bilateral
- Labio-palatal location of the displaced canine: palatal, labial, or center of the arch. The method involves evaluating the position of the anterior face of the canine crown relative to the adjacent teeth (with the lateral incisor serving as the reference point) on a para-sagittal view and/or a transverse view, in order to determine the location of the canine, either vestibularly or palatally, as described by the Lai team in a study conducted in 2013 [7]
- Mesiodistal position of the canine cusp tip according to the modified Ericson S. and Kurol J. sector method by Lindauer and colleagues was employed. It involves determining, on a panoramic radiograph, the position of the canine tip relative to the lateral incisor [8].

    - Sector I: corresponds to the area where the impacted canine appears distal to the lateral incisor and does not overlap the root of the lateral incisor.
    - Sector II: is mesial to Sector I but distal to the longitudinal axis bisector of the lateral incisor.
    - Sector III: is mesial to Sector II but distal to the mesial tangent of the root and crown of the lateral incisor.
    - Sector IV: is mesial to Sector III (Figure 1).

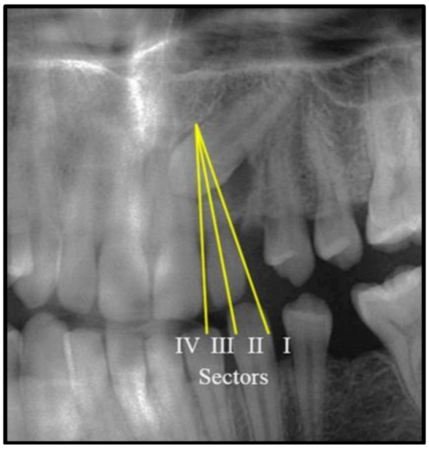

Figure 1: Lindauer *et al*.,'s Sector Technique

- Inclination of the canine to the midline (α angle) on the CPR [9] (Figure 2)
- Inclination of the canine to the adjacent lateral incisor (β angla) on the CPR [9] (Figure 2)
- Inclination of the canine to the occlusal plan (γ angle) on the CPR [9] (Figure 2)

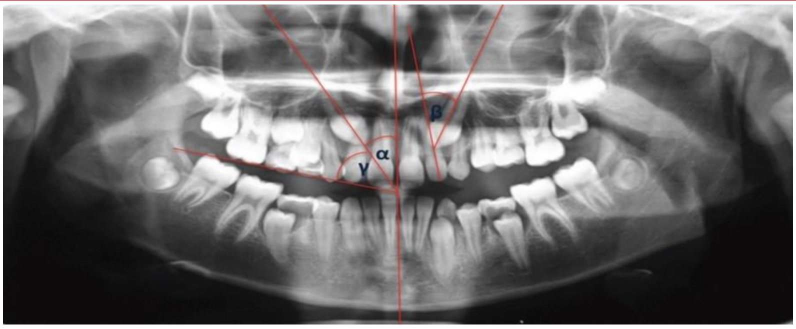

Figure 2: Angulation of the maxillary impacted canine (angles α, β, γ)

- Maximum width of the canine follicle: measured perpendicular from the crown to the follicle periphery on axial views along the canine long axis.

The canine dental follicle graded in 1-mm intervals (0-1 mm: grade 1; 1-2 mm, grade 2; 2-3 mm, grade 3; >3 mm, grade 4) [10] (Figure 3, 4, 5 et 6).

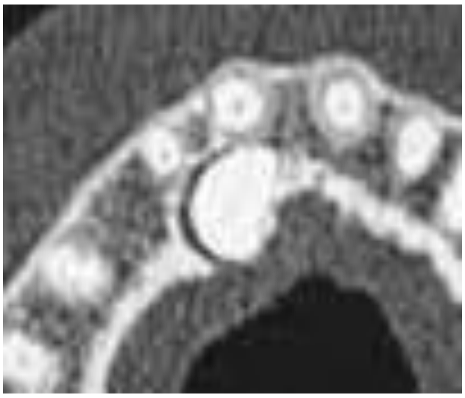
Figure 3: Grade 1 (<1mm)

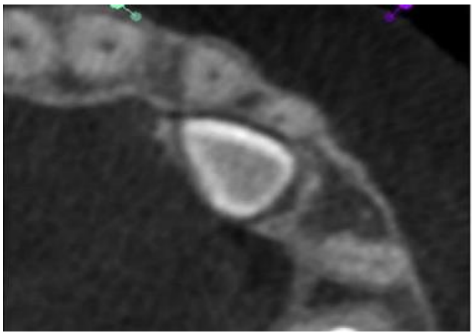
Figure 4: Grade 2 (1-2 mm)

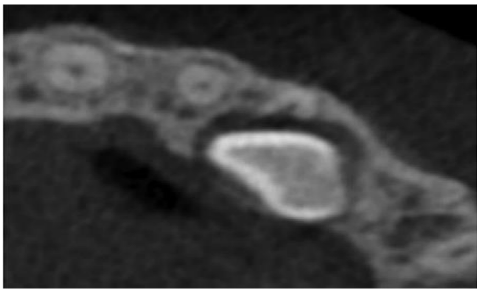
Figure 5: Grade 3 (2-3 mm)

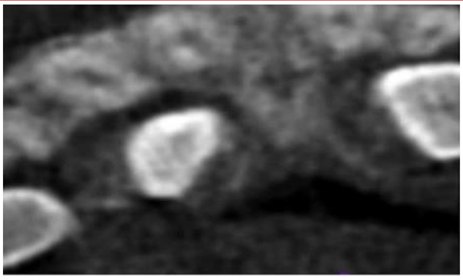

Figure 6: Grade 4 (>3mm)

- Contact relationships between the canine and the adjacent roots: contact if the distance between two teeth was less than 1mm [11] (Figure 7 et 8).

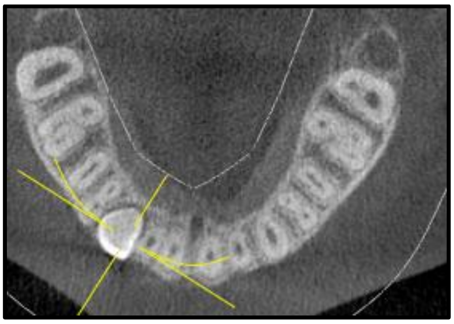

Figure 7: Canine/Lateral Incisor Physical Contact: Cross-sectional View

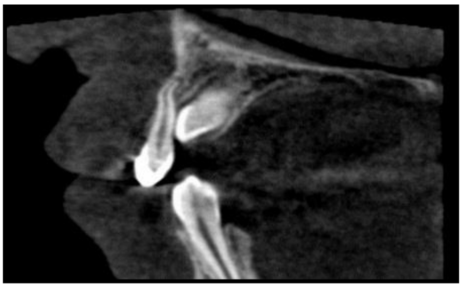

Figure 8: Canine/Lateral Incisor Physical Contact: Para-sagittal section

4. Presence or absence of root resorption (central incisor, lateral incisor, first premolar) was assessed on 3D MPR views along the long axis of every adjacent root. Following variables were recorded:

- ➢ Root resorption: present or absent for every adjacent tooth
- ➢ severity of root resorption according to Ericson and Kurol [12] graded as:
  - No resorption: intact root surface, the cementum layer may have been lost.
  - Slight resorption: resorption up to half of the dentine thickness (Figure 9).
  - Moderate resorption: resorption of the dentine midway to the pulp or more, the pulp lining being unbroken (Figure 10).
  - Severe resorption: resorption reaches the pulp (Figure 11).
- ➢ Vertical location of root resorption: cervical, middle, or apical third.

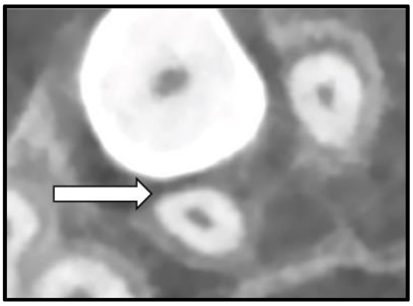

Figure 9: Slight root resorption

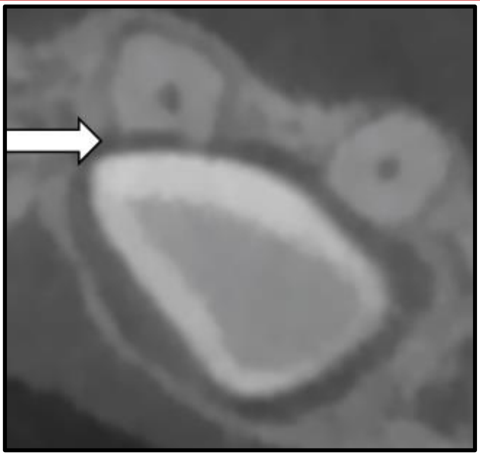

Figure 10: Moderate root resorption

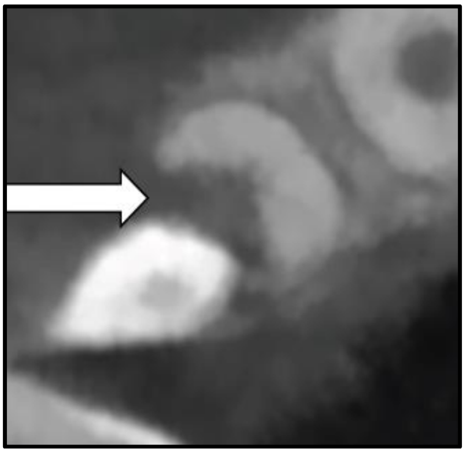

Figure 11: Severe root resorption

Statistical Analysis of Data

All collected data were entered into a computer using SPSS 22 software. Descriptive statistical analysis of quantitative variables was performed by providing position parameters (mean) and dispersion parameters (standard deviation) for each variable to present the results.

In univariate analysis, the association between the dependent variable and qualitative covariates was evaluated using chi-square and Fisher exact tests, while quantitative variables were assessed using the Student's t-test.

Subsequently, multivariate analysis was conducted using a binary logistic regression model. From this analysis, we established a predictive model for root resorption.

To evaluate the performance of this model, we plotted a Receiver Operating Characteristic (ROC) curve using different classification thresholds to determine the model's ability to effectively discriminate cases of root resorption.

The normality of the sample distribution was assessed using the Shapiro-Wilk and Kolmogorov-Smirnov tests. The significance threshold was set at 5%.

RESULTS

Descriptive Results

Seventy patients, comprising 43 females (61.4%) and 27 males (38.6%) aged between 12 and 24 years with a mean age of 17.03 ± 2.818 years, were included in this study.

In our study, we found that the lateral incisor was the most frequently affected tooth by root resorption, with a percentage of (61.1%). Next, the central incisor was the second most affected tooth, with a percentage of (11.1%). Finally, the first premolar exhibited a lower rate of root resorption, with a percentage of (2.2%).

Our study revealed a predominance of mild root resorptions, accounting for 58.2% of cases, whereas moderate root resorptions constituted only 31.8% of cases (Table II).

The descriptive data of the sample is presented in (Table I).

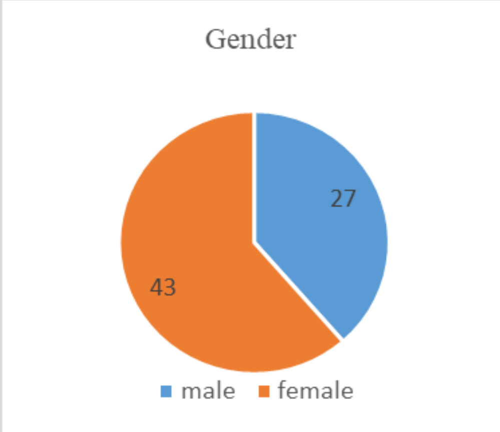

Figure 12: Distribution of the sample according to gender

Table I: Descriptive data of the sample

Patients	**N = 70**		
Impacted canine	N = 90		
Age (mean)	17.03 years		
Gender	male		27 (38.6%)
	Female		43 (61.4%)
Type of inclusion	Unilateral		50 (71.4%)
	Bilateral		20 (28.6%)
side of inclusion	left		43 (47.8%)
	right		47 (52.2%)
Buccopalatal position	buccal		49 (54.4%)
	In midalveolus		1 (1.1%)
	Palatal		40 (44.4%)
Mesio-distal placement of the impacted canine : Analysis of Lindauer	Sector I		22 (24.4%)
	Sector II		21 (23.3%)
	Sector III		15 (16.7%)
	Sector IV		32 (35.6%)
Angulation of the impacted canine	α Angle		26.7 +/-17,523
	β Angle		35.29 +/-17,639
	γ Angle		58.54 +/-17,660
Proximity/direct contact	Lateral incisor	yes	59 (65.6%)
		No	31 (34.4%)
	central incisor	yes	12 (13.3%)
		No	78 (86.7%)
	First premolar	yes	2 (2.2%)
		No	88 (97.8%)

Table II: Descriptive data on the presence of root resorptions and their severity based on the type of tooth

		Lateral incisor		**Central incisor**		**first premolar**		**Total**	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Root Resorption	Absent	35	38.9	80	88.9	88	97.8	203	75.1
	Present	55	61.1	10	11.1	2	2.2	67	24.9
Severeness of resorption	slight	27	32.1	10	20.2	2	10.7	39	58.2
	moderate	28	33.3	0	2.4	0	1.2	28	41.8
	severe	-	-	-	-	-	-	-	-
Location of resorption	Apical third	18	32.7	2	20	2	2.3	22	32.8
	Middle third	31	56.4	8	80	-	-	39	58.2
	Cervical third	3	5.45	-	-	-	-	3	4.5
	Apical + Middle	3	5.45	-	-	-	-	3	4.5

Analytical Results

Factors associated with adjacent tooth resorption (Univariate Analysis)

The univariate analysis shows that angles α, γ, and β are statistically significant factors for both lateral and central incisors with respective p-values of <10^-3 and <0.01 (Table IV).

There is a significant association between age and root resorption in lateral incisors (p < 10^-3).

Patients with contact between the impacted canine and the incisors are more likely to have root resorption (p < 10^-3).

There is a positive and statistically significant association between lateral incisor root resorption and the position of the impacted canine in the mesio-distal direction (p ≤ 10^-3).

There was no association between adjacent tooth root resorption and the following factors:

- Gender.
- Type and side of impacted canine.
- Position of the impacted maxillary canine in the bucco-palatal direction.
- Grade of canine follicles.

Table III: Factors associated with root resorption of adjacent teeth: (Univariate Analysis)

	Prevalence of			Root Resorption					
	Lateral incisor			Central incisor			First premolar		
	RR (+)	RR (-)	P	RR (+)	RR (-)	p	RR (+)	RR (-)	p
Gender: n (%)									
Female	37(67.3)	20(57.1)	0.331	5 (50)	52(65)	0.488	2(100)	55(62.5)	0.530
Male	18(32.7)	15(42.9)		5 (50)	28(35)		0 (0)	33(37.5)	
Age: mean ± ET	18,02±2.26	15.20±2.58	<10-3	17.40±1.84	16.86±2.84	0.562	15.50±2.12	16.95±2.76	0.462
Type of inclusion n (%)									
Unilateral	31(62)	19(38)		3(6.0)	47 (94)		2(4.0)	48(96)	
Bilateral	24(60)	16(40)	0.847	7(17.5)	33(82.5)	0.102	0(0)	40(100)	0.501
Side of inclusionn (%)									
Right	30(63.8)	17(36.2)		3(6.4)	44(93.6)		2(4.3)	45(95.7)	
Left	25(58.1)	18(41.9)	0.580	7(16.3)	36(83.7)	0.184	0(0)	43(100)	0.495
Mesiodistal position n (%)			<10-3			NA			NA

	Prevalence			Of root resorption					
	Lateral Incisor			Central Incisor			First premolar		
Sectorr I N (%)	18(78.3)	5(21.7)		0 (0.0)	23(100)		1(4.3)	22(95.7)	
Sector II N (%)	10(47.6)	11(52.4)		0(0,0)	21(100)		1(4.8)	20(95.2)	
Sector III N (%)	2(14.3)	12(85.7)		0(0,0)	14(100)		0(0,0)	14(100)	
Sector IV N (%)	5(15.6)	27(84.4)		10(31.3)	22(68.6)		0(0,0)	32(100)	
bucco-palatal position n (%)									
buccal N (%)	30(61.2)	19(38.8)		6(12.2)	43(87.8)		0(0)	49(100)	
In midalveolus N (%)	1(100)	0(0)	NA	0(0,0)	1(100)	NA	0(0)	1(100)	NA
Palatal N (%)	24(60)	16(40)		4(10)	36(90)		2(5.0)	38(95)	
α Angle mean ± ET	33.42±16.5	16.14±13 .58	<10-3	41,50+/- 17,26	24.85+/- 16,78	0.004	29,00+/- 26,87	26,65+/- 17,48	0.852
β Angle mean ± ET	42.36±16.31	24.17±13 .54	<10-3	49,50+/- 17,26	33,51+/- 16.96	0.006	37,00+/- 26.87	35,25+/- 17,60	0.891
γ Angle mean ± ET	51.84±16.74	69.09±13 .6	<10-3	43,7+/- 17,12	60.4+/- 16.92	0.004	56,00+/- 26,87	58,6+/- 17,62	0.838
Contact with adjacent roots			<10-3			<10-3			1

	Prevalence			Of Root resorption					
	Lateral Incisor			Central Incisor			First permolar		
Yes N (%)	55(93.2)	4(6.8)		1(1.3)	77(98.7)		0(0,0)	2(2,3)	
No N (%)	0(0)	31(100)		9(75)	3(25)		2(100,0)	86(97,7)	
Follicule size									
Grade 1 N (%)	6(18.2)	27(81.8)		0(0,0)	33(100)		0(0)	33(100)	
Grade 2 N (%)	17(85)	3(15)	NA	0(0,0)	20(100)	NA	1(5.0)	19(95)	NA
Grade 3 N (%)	30(85.7)	5(14.3)		9(25.7)	26(74.3)		1(2.9)	34(97.1)	
Grade 4 N (%)	2(100)	0(0)		1(50)	1(50)		0(0,0)	2(100)	

Table IV: Risk factors for root resorption (Multivariate Analysis) using the Binary Logistic Regression model

		P	Odds Ratio (OR)	IC 95% d'OR
α Angle		**0,023**	1.059	[1,008, 1,112]
Age		**<10-3**	1.927	[1,394, 2,663]
Mesiodistal placement Analysis of Lindauer	Sector I/II (reference)	**-**	-	-
	Sector III/IV	**0,004**	8,591	[1,997, 36,951]
	Sector I (reference)	**-**	-	-
	Sector II	0.206	-	-
	Sector III	**0.009**	12.001	[1.851, 77,797]
	Sector IV	**0.029**	6.148	[1,203, 31,421]

Among the 12 variables included in the final multivariate prediction model (Table III), age, α angle, and mesiodistal placement of the impacted canine are strong predictors of root resorption (Table IV).

The predictive formula for the probability of root resorption presence is as follows:

$$\text{Probabilité de RR} = \frac{\mathbf{1}}{\mathbf{(1+exp^{-\mu})}}$$

To assess the performance of this model, we generated a ROC curve using various classification thresholds to determine its effectiveness in discriminating cases of root resorption. The coefficient of determination between the equation of the discriminant function and actual root resorption was estimated at R2 = 0.650. Analysis of the ROC curve revealed that the area under the curve was a commendable 92.2%. The cutoff threshold value, which provided both the highest sensitivity (90.9%) and specificity (82.9%), was selected at a value of -0.1625 (Figure 13). The discriminant function was statistically significant ($p < 0.001$). The formula correctly predicted root resorption in 86.7% of the subjects.

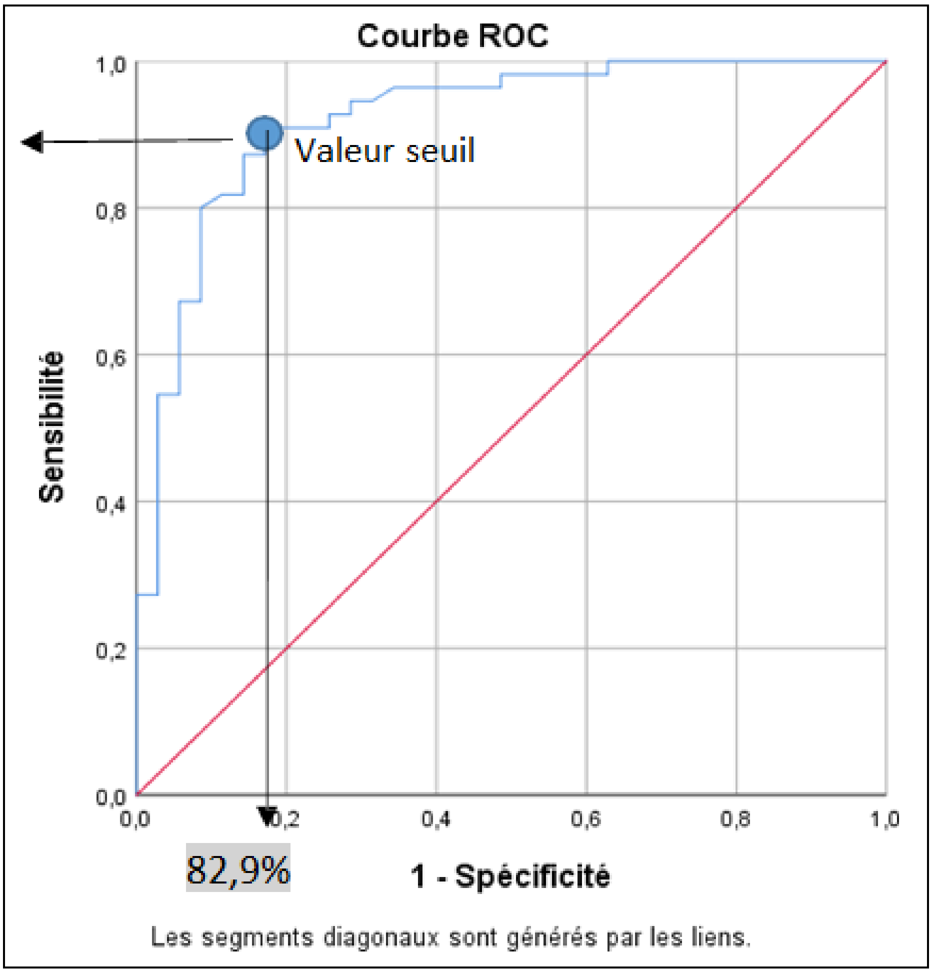

Figure 13: The ROC Curve of the final prediction model derived from the multivariate analysis

DISCUSSION

The occurrence of disruptions in the eruption of maxillary canines appears to fluctuate between 1 to 3 percent, with females showing a higher susceptibility. Our research, which had a higher proportion of female participants, almost a 2:1 ratio, aligns with this trend. Walker *et al.*, (2005) [13] suggest that the difference in overall craniofacial growth and development between the sexes and genetic factors could contribute to this phenomenon.

Another factor may be that females tend to seek orthodontic treatment more often than males.

The impaction of the canine can cause several complications, with root resorption being the most common.

While previous studies mainly focused on prevalence, our study aimed to identify properties of impacted canines influencing root resorption. Table 2 shows that gender, the distinction between right and left tooth positioning and the buccopalatal position did not exhibit significant differences.

Prevalence, severity and localization of root resorption

Our results indicate a rate of 61.1% of impacted canines causing adjacent tooth root resorption, as revealed in Table II. This proportion is higher than that observed in the Chinese and French populations, where the rates were 50.7% and 48.2%, respectively [14, 15]. However, it is lower than the incidence of adjacent tooth resorption observed in the Jordanian and American populations, which was 74% and 77.8%, respectively [16, 17]. Furthermore, the prevalence of affected adjacent teeth is 24.9% in our sample. This incidence is lower than the rates reported in the literature. These variations could be due to differences in population samples, evaluation methodologies, or other study-specific factors.

On the side of the "impacted canine," it was found that 59.6% of root resorptions were mild, while only 34.6% were moderate (Table II). This predominance of mild resorptions exceeds the findings of a 2018 meta-analysis of 18 studies, which concluded that root resorptions would be predominantly mild (43.2%) and severe in 30.9% of cases [18]. This result disagrees with Ericson and Kurol (2000) [19] who reported that an even higher percentage of severe root resorption in their study, with 60% of lateral incisors and 43% of central incisors showing root resorption that exposed the pulp.

Our results show that the apical and middle thirds were the most resorbed in our sample, with respective percentages of 56.4% and 32.6%. This finding is in disagreement with Ericson and Kurol [20], who found that 82% of lateral incisors were affected at the middle third and 13% at the apical level. Yan *et al*., found that in the Chinese population, the apical third was the most affected, which is consistent with our results. In contrast to white populations, the prevalence of root resorption at the middle third was highest, with a minimal proportion located apically and cervically. These discrepancies in the prevalence of resorption locations between different studies could result from variations in the imaging methodologies used, classification criteria for resorptions, or variations related to ethnicity.

Association between Sexe and root resorption:

In our study, we found no association between gender and root resorption. However we found that the prevalence of root resorption is more frequent in females, with a female-to-male ratio of 2 in our study which was also documented in previous reports.

Chaushu *et al*., [10] found a 4.2 times higher risk of developing severe root resorptions among female individuals, while Kim [21] reported a 4-fold increased risk.

The hypothesis of hormonal influence factors is suggested by the authors mentioned above.

According to Alemam *et al*., [17], the gender factor should be cautiously considered due to the high female-to-male ratio. The limited number of male subjects included in our study may have impacted the results, likely because male subjects less frequently seek orthodontic treatment.

Association between age, angulation, mesiodistal placement of the impacted canine an root resorption

A statistically significant difference was observed between cases exhibiting RR in the incisors when the canine was located in sectors I and II compared to those in sectors III and IV.

These observations are consistent with the findings obtained in previous studies on the Asian population.

In our study the multivariate analysis revealed that an impacted canine located in sectors III or IV increases the risk of RR by 8 times compared to a canine located in sectors I and II (Table IV).

Previous studies such as Ericsson and Kurol (1988) [22] have also confirmed this observation by demonstrating that an impacted canine erupting medially to the long axis of the adjacent lateral incisor (sectors III and IV) and inclined ≥25° to the midline of the jaw increases the risk of RR by 50%.

In the other hand, Lai and Lui [7, 14] did not find a significant association between the inclination of the canine relative to the midline and RR.

According to this multivariate analysis, angle α, age, and mesiodistal placement of the impacted canine were identified as potential risk factors associated with RR of adjacent teeth with respective significance levels of (p=0.023, p<10^-3, p=0.004). This analysis reveals an Odds Ratio (OR) of 1.059 for angle α.

In contrast, Guarnieri [23] found that the β angle is a more important predictive factor than Lindauer's sector analysis for assessing RR risk.

According to his findings:

A β angle greater than 54° is associated with A canine located in sector II, III or IV increases the probability of RR (>61%).

Conversely, a β angle less than 18° associated with a canine in sector I presents a negligible RR probability (<0.06%).

Association between physical proximity and root resorption:

Our study did not demonstrate a significant association between the width of the dental follicle of impacted maxillary canines and the presence of RR in adjacent teeth, which is also consistent with findings reported in the literature.

The etiology of root resorption remains unclear. It has been suggested that enlarged dental follicles and the pressure exerted by an erupting tooth may contribute to the root resorption of adjacent teeth (Marks *et al*., 1997) [24]. However, Ericson and colleagues (2001) concluded, based on a CT examination, that the dental follicle is not responsible for root resorption of permanent teeth. Instead, they found that resorption of the permanent maxillary incisor is primarily caused by physical contact between the incisor and the canine, as well as direct pressure from the canine during the eruption process (Ericson *et al*., 2001) [5].

Our results are consistent with these findings, showing, through CBCT imaging, that the dental follicle of the impacted canine can frequently expose the roots of maxillary incisors due to its guidance during eruption, often disrupting the periodontal contours without resorbing the hard tissues of the incisor roots.

Indeed, this follicle can prevent direct contact between the enamel of the canine and the cementum of the incisor root. Morphological and histological studies have shown that the dental follicle of the canine often exposes the root of the adjacent incisor during eruption without resorbing its cementum or hard tissues if eruption proceeds normally [20].

Ericson's research suggests that while the dental follicle may induce resorption of the periodontal contour, it cannot directly affect the hard tissue of the root. Additionally, Ericson proposed that the primary mechanisms driving root resorption involve physical contact, active pressure, and cellular activities occurring at the point of contact between the canine crown and adjacent root. It is reasonable to anticipate that increased overlap between the canine crown and lateral incisor root would lead to a higher likelihood of physical contact between them.

This contact relationship (physical proximity of less than 1 mm) is consistent with what has been reported in the literature as the strongest predictive factor for the occurrence of RR [11]. These findings are corroborated by the meta-analysis by Schroder et al., which reveals that RR of maxillary incisors is correlated with their contact with maxillary canines during eruption [18].

The mechanism of RR following canine impaction and the factors involved in the process are not clear. Resorptions may be caused by physical pressure due to the migration of the impacted canine [25, 26]. During the eruption of the maxillary canine, the alveolar barrier of the adjacent incisor will be temporarily resorbed [5], and the normal protective layer of cementoblasts and collagen fibers will disappear, opening the way for dentinoclasts.

The close relationship between the physical contact between the crown of the impacted canine and RR of adjacent teeth indicates that the crown is responsible for eruption. Through orthodontic treatment, it is well-known that physical pressure on hard tissues induces cellular activity in the periodontal membrane and the formation of dentinoclasts and osteoclasts. These observations indirectly verify the theory that active pressure during the eruption of permanent teeth, as part of the eruptive mechanism, is the factor that triggers root resorption of the incisor. The strong association between incisor root resorption and contact with the adjacent erupting canine, as observed in this study, supports this theory.

According to Yan *et al*., [11], the biological mechanisms explaining why physical proximity increases the risk of root resorption have not been systematically studied. In their study, a "contact" measure was assigned when the boundaries of the crown of the impacted canine and the adjacent root were within 1 mm. This criterion provides a practical and clinically acceptable method for quantitative measurements from CBCT images [27, 28].

The proximity < 1 mm suggests that RR in adjacent roots could be caused by direct physical damage, increased pressure on the cementum and dentin, or the presence of concentrated resorptive molecules from the erupting canine follicle.

Because our radiological images cannot capture cellular and molecular details, these potential mechanisms remain speculative until confirmed by future histological and biological studies.

CONCLUSION

Prediction of RR based on panoramic radiographs is difficult. The final prediction model for RR based on available panoramic radiographs may help justifying the need of additional CBCT examination

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