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Root Resorption of Adjacent Teeth Associated with Maxillary Canine Impaction in the Saudi Arabian Population: A Cross-Sectional Cone-Beam Computed Tomography Study

Ahmed Mohammed Alassiry [1] and Zaki Hakami [2,*]

[1] Department of Preventive Dental Sciences, Faculty of Dentistry, Najran University, Najran 55461, Saudi Arabia; amyahia@nu.edu.sa

[2] Division of Orthodontics, Department of Preventive Dental Sciences, College of Dentistry, Jazan University, Jazan 45142, Saudi Arabia

* Correspondence: zhakami@jazanu.edu.sa; Tel.: +96-6544702011

Abstract: This study aimed to identify the location of root resorption in relation to an impacted maxillary canine and grade its severity using cone-beam computed tomography (CBCT) in the Saudi Arabian population. Materials and Methods: CBCT scans of 169 patients with maxillary canine impaction were evaluated. The location and the severity of root resorption of the affected tooth in relation to the impacted maxillary canine were recorded for each patient. Results: a total 204 impacted maxillary canines caused root resorption in 218 adjacent teeth. Maximum root resorption was present in 63.3% of the apical one-third of the root and 37.6% of the palatal surfaces. There was mild root resorption in 55%, moderate in 10% and severe in 35%. There was no statistically significant difference between the gender, age, type of impaction, side of impaction, and the number, location, or degree of root resorption. Multiple logistic regression models showed significant association (p = 0.024) between gender, type of impaction, and root resorption. A significant correlation was found between the level and the surface of the root resorption (p = 0.018). Conclusion: In the Saudi population, apical one-third root levels and palatal surfaces were primarily involved in root resorption caused by impacted canines. The females with bilateral canine impaction were more likely affected by root resorption.

Keywords: impacted canine; CBCT; root resorption; lateral incisor; Saudi Arabia

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1. Introduction

Maxillary canine impaction is a common clinical finding that often is noticed during routine orthodontic observation. After third molars, maxillary canines are the most frequently impacted teeth, with 1–3% prevalence in the general population [1–3]. In contrast to the third molar, the maxillary canine is in a highly demanding esthetic and functional region, leading to its greater role in orthodontics [4]. Root resorption (RR) of an adjacent tooth is an undesirable yet significant consequence of an impacted maxillary canine. It is an irreversible, aseptic, and adverse sequela leading to the progressive loss of cementum and dentine from the adjacent teeth in relation to the impacted maxillary canine [5].

Several potential radiographic predictors have been identified for the RR of teeth associated with impacted maxillary canines. These include the width of the canine and adjacent teeth, canine angulation and distance to reference planes, canine vertical relationships, canine position and overlap, dental anomalies, and canine follicle size [6–13]. Canine contact or physical proximity of ≤1 mm to an adjacent root is considered the most important predictor for root resorption [10,14,15].

Root resorption is clinically asymptomatic, difficult to identify, and most difficult to treat. Since root resorption lacks symptoms, it tends to be diagnosed late [16]. Excessive pressure from the localized impacted tooth stimulates the resorbing cells and leads to root resorption. Removal of this source of mechanical irritation can slow the resorption process and allow the root to repair [17]. In cases where resorption has compromised the tooth's blood supply, treatment can be a daunting task that requires endodontic treatment. In severe cases, elective extraction of the resorbed tooth might be the only viable option. Hence, early and precise identification and diagnosis of an impacted canine are paramount in good orthodontic practice. A study has found that the facial biotype detectable in lateral cephalometric radiographs has a predictive value in canine impaction [18].

It has been shown that impacted canines can lead to different severity levels of RR at all root levels and surfaces [19]. In the past, traditional two-dimensional radiographic techniques, such as orthopantomogram, cephalogram, and periapical and occlusal radiographs, have been used for the localization of impacted canines and the identification of RR. These methods provide poor clinical information due to contrast, distortion, superimposition, and artifacts [20]. With the advancement of three-dimensional imaging and the advent of cone-beam computed tomography (CBCT), the diagnosis of RR has improved significantly. This can be attributed to the sensitivity and accuracy of CBCT in its ability to detect RR [8,21]. Although the radiation dose is higher in CBCT than conventional methods, it is lower than other imaging techniques such as computed tomography (CT) [22]. Considering this cost-benefit ratio, CBCT is currently the imaging choice for the identification and localization of an impacted maxillary canine and its associated root resorption in adjacent teeth.

Several studies have evaluated the prevalence, location, and severity of maxillary canine impaction and root resorption in various regions and ethnic populations around the world [19]. To the best of our knowledge, no study has been conducted to identify the location and severity of root resorption associated with an impacted maxillary canine in the Saudi population. Therefore, this study aims to identify the location of root resorption in relation to the impacted maxillary canine and grade its severity using CBCT in a Saudi Arabian population sample.

2. Materials and Methods

This study is a retrospective and cross-sectional study in which the CBCT scans of 169 patients who visited Najran Dental Center for orthodontic treatment were randomly selected. The patients had approached the dental department for orthodontic treatment and were subsequently referred for radiographic imaging of their impacted maxillary canine between 2015–2019. Patients of Saudi Arabian origin and 15–35 years of age were included in the study. Patients with a craniofacial syndromic condition or other systemic bony diseases, supernumerary teeth, odontomas, or odontogenic tumors or cysts associated with an impacted maxillary canine were excluded. Patients in mixed dentition or with an ongoing or previous history of orthodontic treatment were also excluded. The study protocols were approved by the ethical committee at the Faculty of Dentistry, Najran University.

All the CBCT scans were obtained from the same machine. The exposure parameters were a tube voltage of 120 kVp, a tube current of 15 mA, and a scanning time of 27 s. All patients were scanned in a standing position using a 12-inch diameter field of view (FOV), a 0.376 mm slice thickness, and a total of 512 slices in Digital Imaging in Communications in Medicine (DICOM) format. The scan images were reconstructed in all three sagittal, axial, and coronal planes. The 3D CBCT images were analyzed on a flat-screen monitor by a single orthodontist (A.M.A). The images were adjusted by the investigator for brightness and contrast to optimize the image quality for the best display of root resorption.

The following observations were made and recorded by a single examiner for each CBCT scan image:

1. Type of impaction: unilateral or bilateral
2. Side of impaction: left or right
3. Number of teeth resorbed
4. Type of tooth/teeth resorbed
5. Location of resorption in relation to the root level: apical third, apical and middle thirds, middle third, middle and cervical thirds, cervical third, or apical, middle, and cervical thirds

6. Location of resorption in relation to the affected surface: mesial, distal, buccal, palatal, mesiopalatal, distopalatal, mesiobuccal, distobuccal
7. Severity/degree of resorption in the axial plane using Ericson and Kurol's classification from 2000 [23]:

Grade 1: Intact root surfaces except for the loss of cementum
Grade 2: Slight resorption, up to half of the dentine thickness to the pulp
Grade 3: Moderate resorption, halfway to the pulp or more; the pulp is covered with dentine
Grade 4: Severe resorption; the pulp is exposed

The complete data was entered in Excel software (Microsoft Corp., Redmond, WA, USA) and statistically analyzed using SPSS, Version 20 (IBM Corp., Armonk, NY, USA). An intra-examiner test was performed to assess the reliability of the measurements. Around 20 CBCT scans were randomly selected and re-analyzed after a two-week interval by the same examiner. Intraclass correlation coefficient (ICC) was used to calculate the correlation between two sets of readings. Descriptive analysis was used to obtain the mean and standard deviation of age in the sample. Pearson's chi-square test was used to determine the relationship between gender and the type of impaction (unilateral or bilateral) and side of impaction (left or right). ANOVA statistics were used to identify the relationship between age, location, and severity of resorption. The Kruskal–Wallis test was used to identify the relationship between gender, location, and severity of resorption. The Poisson regression model was used to determine any relationship between age, gender, number of impacted teeth, and number of resorbed teeth. A p-value of <0.05 was considered to be statistically significant.

3. Results

CBCT scans of 169 subjects were evaluated for impacted maxillary canines, as shown in Table 1. The sample consisted of 71 males and 98 females with a mean age of 20.34 ± 8.9 and 19.65 ± 9.6 years, respectively. In this total sample, 204 impacted maxillary canines were present, which caused resorption in 218 adjacent teeth. Around 54 (40%) males and 80 (60%) females, a total of 134 patients, had unilateral impaction. Around eight (23%) males and twenty-seven (77%) females, a total of thirty-five patients, had bilateral impactions. In 94 patients, the impaction was on the left side, with 42 (44.7%) in males and 52 (55.3%) in females. Impaction on the right side was present in 110 patients, with 50 (45.45%) in males and 60 (54.55%) in females. Intraclass correlation coefficient (ICC) found a high correlation (>0.8) between two sets of readings. No statistical difference was found in two sets of readings ($p > 0.05$).

Table 1. Patient's descriptive data regarding age, gender, and features of maxillary canine impaction.

Variable	Male	Female	Total
Patients	71 (42%)	98 (58%)	169 (100%)
Age (years)	20.34 ± 8.9	19.65 ± 9.6	20.64 ± 9.81
Unilateral impaction	54 (40%)	80 (60%)	134 (100%)
Bilateral impaction	8 (23%)	27 (77%)	35 (100%)
Left side	42 (44.7%)	52 (55.3%)	94 (100%)
Right side	50 (45.45%)	60 (54.55%)	110 (100%)
Total impacted canines	92 (45%)	112 (55%)	204 (100%)

The resorbed teeth comprised of 38 (17.4%) central incisors, 162 (74.3%) lateral incisors, 16 (7.3%) first premolars, and two (0.9%) first permanent molars, as shown in Table 2. Maximum root resorption was present in the apical one-third (63.3%) of the affected teeth. Apical and middle one-third showed 12% root resorption, middle one-third 9.7%, middle and cervical one-third 6.8%, cervical one-third 5%, and apical, middle, and cervical one-third showed 3.2%.

Table 2. Location of root resorption of the affected tooth in relation to the root level.

Affected Teeth	Location of Root Resorption in Relation to the Root Level (Number)						
	Apical 1/3	Apical & Middle 1/3	Middle 1/3	Middle & Cervical 1/3	Cervical 1/3	All Surfaces	Total (%)
Central Incisor	26	4	4	1	2	1	38 (17.4%)
Lateral Incisor	102	20	15	12	8	5	162 (74.3%)
First Pre-molars	10	2	1	1	1	1	16 (7.3%)
First Molars	0	0	1	1	0	0	2 (0.9%)
Total	138 (63.3%)	26 (12%)	21 (9.7%)	15 (6.8%)	11 (5%)	7 (3.2%)	218 (100%)

All the root surfaces were involved in resorption. Maximum root resorption was in relation to the palatal surface (37.6%), followed by the distal (14.7%), mesial (11%), buccal (10%), distopalatal (9.7%), distobuccal (7.3%), and mesiobuccal (1.8%) surfaces, as shown in Table 3. In terms of severity or degree of root resorption, 55% of the affected teeth had slight resorption, 10% had moderate, and 35% had severe resorption, as shown in Table 4.

Table 3. Location of root resorption of the affected tooth in relation to the root surface.

Affected Teeth	Location of Root Resorption in Relation to Root Surface (Number)								
	Mesial	Distal	Buccal	Palatal	Mesio-palatal	Disto-palatal	Mesio-buccal	Disto-buccal	Total (%)
Central Incisor	0	7	2	14	6	5	0	4	38 (17.4%)
Lateral Incisor	14	24	20	64	9	16	3	12	162 (74.3%)
First Premo-lars	9	1	0	4	2	0	0	0	16 (7.3%)
First Molars	1	0	0	0	0	0	1	0	2 (0.9%)
Total	24 (11%)	32 (14.7%)	22 (10%)	82 (37.6%)	17 (7.8%)	21 (9.7%)	4 (1.8%)	16 (7.3%)	218 (100%)

Table 4. Severity or degree of root resorption of the affected tooth.

Affected Tooth	Degree of Resorption (Number)			
	Slight	Moderate	Severe	Total (%)
Central Incisor	20	3	15	38 (17.4%)
Lateral Incisor	90	16	56	162 (74.3%)
First premolar	10	2	4	16 (7.3%)
First molar	0	1	1	2 (0.9%)
Total	120 (55%)	22 (10%)	76 (35%)	218 (100%)

There was no statistically significant difference between the gender, age, type of impaction, side of impaction, or the number of teeth resorbed on various statistical analyses. There was no significant correlation between gender, number, location, or degree of root resorption. A significant correlation was found between the level and surface of root resorption ($p = 0.018$). The apical one-third of the root level was significantly more resorbed on the palatal root surface of the affected teeth. A significant association ($p = 0.024$) was found between the gender, type of impaction, and root resorption on applying multiple logistic regression models. The females with bilateral canine impaction were more affected by root resorption.

4. Discussion

Root resorption associated with an impacted maxillary canine can rapidly progress to threaten the vitality of the affected tooth. Hence, it is clinically important to diagnose and treat the condition as soon as it is noticed. Previously, the first study employing two-dimensional radiographic techniques noticed a prevalence of only 12% root resorption due to impacted canines [24]. Buccal and palatal canine impactions were more difficult and less reliable to diagnose with conventional two-dimensional techniques [25]. With the advancement in three-dimensional imaging like CBCT, more reliable information can be obtained than conventional methods. When directly comparing two- and three-dimensional imaging techniques on the same patients, Botticelli et al. found more precise, detailed, and accurate management of an impacted canine with three-dimensional CBCT imaging [26]. CBCT is a low-cost and low radiation dose alternative to conventional computed tomography (CT), which has also been used to detect root resorption. Owing to its maximum spatial resolution, CBCT allows for the detection of root resorption of as low as 300–500 μm [27]. Moreover, the high image quality of CBCT scan sets permits finer detection of root resorption than CT images [28]. Such is the superiority and convenience of CBCT that it has now become the imaging modality of choice for detecting root resorption associated with an impacted maxillary canine.

CBCT being used more routinely in standard orthodontic care has invariably led to an increase in root resorption detection and prevalence rates in various populations. In this study of the Saudi population, at 74.3%, the lateral incisors were the most affected teeth with root resorption, followed by central incisors at 17.4%, first premolars at 7.3%, and first permanent molars at 0.9%. The findings of this study are in accordance with the results of other studies that have reported lateral incisors as the most affected tooth with root resorption associated with maxillary canine impaction [10,14,29]. A recent systematic review and meta-analysis conducted by Schroder et al. found a high prevalence of root resorption in the lateral incisor associated with contact with an impacted maxillary canine [19]. They reported that around 8.20%–89.61% lateral incisors, 1.19%–35.06% central incisors, and 4.48%–11.72% premolars were affected by root resorption associated with an impacted maxillary canine. This maximum incidence of root resorption is seen in lateral incisors that come into contact with the crown of the impacted canine. The physical pressure from the erupting canine can lead to activation of tooth-resorbing cells, odontoclasts, leading to the loss of cementum or dentine from the tooth surface, causing root resorption [13]. Nevertheless, resorption can occur in the central incisor, premolar, or even molar, depending on the immediate vicinity of the impacted canine [30]. Interestingly, no association has been found between the proximity or size of the dental follicle of the erupting maxillary canine with root resorption [6].

Root resorption can affect any level and surface of the tooth depending on the displacement of the maxillary canine. In this study, the apical one-third (63.2%) was the most involved level of root resorption, followed by the apical and middle one-third (12%). The least amount of root resorption was present in the aspect involving all three root levels, i.e., the apical, middle, and cervical one-third (3.2%). These findings agree with many other studies, including a recent systematic review and meta-analysis that reported that root resorption occurs most commonly in the apical one-third of the tooth associated with an impacted maxillary canine [19]. Clinically, the root resorption in the apical one-third region destroys less dentine than the middle or cervical region. Hence, the level of resorption can aid in accurate diagnosis and prove to be a prognostic factor for treating resorptions. On visualizing the root resorption three-dimensionally in this study, it was observed that the palatal surfaces of the root were affected most severely at 37.6%, followed by the distal surface at 14.7%; the least affected was the mesiobuccal surface at 1.8%. Dogramaci et al. also reported maximum involvement of the palatal surface [31], but Ericson and Kurol found that the distopalatal surface was most affected with root resorption involving an impacted maxillary canine [23]. The apical one-third of the root is more prone to come in close contact with the crown of an impacted maxillary canine. Moreover, the crown of the erupting maxillary canine is directed palatally with respect to the primary canine and the developing first premolar, implying the path of eruption in the palatal direction. This could be a plausible explanation of maximum root resorption being associated with the apical one-third level and the palatal surface of the roots of the tooth involved with maxillary canine impaction.

In this study, we have used the criteria suggested by Ericson and Kurol in 2000 to grade the severity of root resorption [23]. Since CBCT cannot detect structures with <300 μm, a grade 1 severity level of the classification has not been considered [28]. The thickness of the cementum is 10–50 μm, and its evaluation is more suitable by histological methods. In this study, 55% of affected teeth have shown slight resorption, 10% moderate, and 35% severe resorption with pulp exposure. Ericson and Kurol reported 60% severe and 9% moderate root resorption [8]. Oberoi reported 35% slight and 4% severe root resorption [20]. Severe root resorption has been reported in the literature at 8.1% by Alqerban et al. [5], 8.1% by Akkuc [32], 11.9% by Walker et al. [30], 12.7% by Lai et al. [13], 19.6% by Liu et al. [14] and 30% by Dogramaci et al. [31]. This study's findings vary with other studies due to the high variability in the classification and categorization of root resorption severity. Nevertheless, any root resorption makes the tooth vulnerable to irreversible pulpal damage and increased mobility. This, in turn, can affect the long-term prognosis and the functional benefits of the tooth.

This study also found that females in the Saudi population with bilateral canine impaction were more likely to be affected by root resorption. This can be attributed to the fact that more females show up for orthodontic treatment and are thereby diagnosed with canine impaction. Moreover, sexual dimorphism and genetic and hormonal factors play a significant role in such outcomes. However, the role of bilateral impactions in increasing the severity of impaction needs to be further investigated. Lai et al. [13] and Chaushu et al. [33] found a significant association between gender (female) and root resorption. Other investigators have found no association between age, gender, type of impaction, side of impaction, or the number of teeth resorbed [34,35]. Further studies with better CBCT machines, different voxel resolutions, evaluation of potential risk factors, and a large sample population can be conducted in the near future.

Clinical management of impacted canines and associated root resorption can be complex and frustrating for the orthodontist and their team. When evaluating a patient for the first time, after thorough clinical and radiological investigations, the patient should be informed about the severity of root resorption. A mild to moderate degree of root resorption can only be dealt with using an endodontic treatment. Severe cases of root resorption might require the extraction of the affected tooth instead of the premolar to bring the impacted canine in occlusion. These factors should be considered before commencing the treatment, and the patient should be made aware of the risks and benefits associated with it. If the patient declines the orthodontic treatment, they should be advised for regular review to evaluate the effect of root resorption. If the orthodontic treatment is already in progress and the resorption is diagnosed halfway, the patient should be informed of the scenario, and major changes in the treatment plan can be deemed necessary. If asymptomatic and immobile, a resorbed tooth can be kept for an esthetic and functional purpose for subsequent prosthodontic rehabilitation [36,37].

5. Conclusions

CBCT allows precise and accurate visualization, localization, and grading of root resorption and impacted canines. In this study, CBCT has been used with similar intent to identify the location and severity of root resorption associated with an impacted maxillary canine in the Saudi Arabian population. The following conclusions can be drawn from this study:

1. Lateral incisors (74.3%) were the most affected teeth with root resorption associated with an impacted maxillary canine, followed by central incisors (17.4%), first premolars (7.3%), and first permanent molars (0.9%).
2. All the root levels were involved in resorption. Maximum root resorption was present in the apical one-third (63.3%) of the affected teeth. The least root resorption was in the apical, middle, and cervical one-third (3.2%) level.
3. All the root surfaces were involved in resorption. Maximum root resorption was in the palatal surface (37.6%), and the least was in the mesiobuccal (1.8%) surface.
4. Slight root resorption was present in 55% of the affected teeth, 10% had moderate, and 35% had severe root resorption amounting to pulpal exposure.
5. The Saudi females with bilateral canine impaction had more probability of being affected by root resorption.

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