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original article

Impacted maxillary canine: Assessment of prevalence, severity and location of root resorption on maxillary incisors: A retrospective CBCT study

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Keywords
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Summary

Background > The maxillary permanent canine is one of the most frequently impacted teeth, which often requires multidisciplinary management. A common complication of canine impaction is root resorption of the adjacent dentition. The aim of this retrospective study was to report the prevalence of root resorption of maxillary incisors adjacent to impacted maxillary canines from small volume CBCT images by trained clinicians. A secondary objective was to report the location and severity of root resorption.

Material and methods > CBCT images of patients with impacted maxillary canines (unilateral and bilateral) who attended a joint orthodontic/surgical multidisciplinary clinic were screened. Descriptive statistics were used to investigate associations of patient characteristics and presence of root resorption. Generalized estimating equations (GEE) logistic regression model were used to identify predictors of root resorption.

Results > In all, 148 impacted maxillary canines (122 patients) were analysed. The majority of patients were under 18 years of age (71.6%) with impacted canines present in more females (68.2%) than males (31.8%). Maxillary lateral incisors showed the highest prevalence of root resorption (38.5%). The apical region was the most common location of resorption for lateral incisors (20.9%) with a variable degree of severity evident: slight (10.1%), moderate (15.6%), and severe (12.8%). Although no significant predictors of root resorption were identified, a weak association was evident for age and root development.

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Conclusions > In this cohort of patients, the roots of maxillary lateral incisors are most likely to suffer from root resorption in the presence of an impacted maxillary canine. Clinicians should consider the extent, location and severity of resorption of adjacent teeth when planning treatment decisions and mechanics in cases of impacted maxillary canines.

Introduction

The maxillary permanent canine is the most frequently impacted tooth after the third molar [1]. The reported incidence of impacted maxillary canine ranges between 0.9–3% and is found to be twice as common in females compared to males [2,3]. A multifactorial aetiology has been proposed with factors such as genetic [4], diminutive or absent maxillary lateral incisors [5], long path of eruption [6], arch length discrepancies [7], and pathological factors implicated [3]. A complication of abnormal eruptive processes of impacted maxillary canines is root resorption of the adjacent teeth [8–10]. Root resorption occurs more in females [11] but the reported incidence varies depending on the type of radiological image (2D and 3D) [8,9]. Typically, the maxillary lateral incisor is affected with the prevalence of root resorption reported between 8.2–89.6% [12–14]. The maxillary central incisor, and first and second premolars can also be affected [10–12,14,15], but this is less likely. The position of the canine, root morphology of the first premolars, contact relationship and stage of canine development have all been proposed as risk factors for root resorption of adjacent teeth [10,11,16,17]. Early diagnosis and interceptive treatment were found to be beneficial in normalizing the eruption pathway of displaced canines [18,19]. Despite this, a multidisciplinary approach involving surgical exposure and orthodontic alignment is often required to aid eruption of the canine into the anatomically correct position [20]. Radiographic imaging is routinely used to accurately determine the position of the impacted canine, aiding surgery as well as planning orthodontic treatment mechanics. 3D imaging in particular has been found useful to detect associated pathology [21], such as any root resorption. Pressure from the erupting canine and physical contact between the canine and adjacent teeth have all been attributed as the cause of root resorption [8]. Cone-beam computed tomography (CBCT) has been shown to be more accurate compared to conventional plain 2D radiographs in the assessment of impacted maxillary canines [22] and detection of root damage to adjacent teeth [23,24]. Regarding the latter, knowledge of the positionally relationship of impacted canine in relation to the maxillary incisors can help to plan efficient orthodontic mechanics to align the canine and avoid further resorption of the incisors. CBCTs have also been shown to improve treatment planning of impacted canines [15,25].

Given their importance in the clinical management of impacted canines, accurate interpretation of CBCT images is essential to localize any factors, which may influence treatment decisions and orthodontic mechanics, which may be utilized in the clinical management of the case.

The aim of this retrospective study was to report the prevalence of root resorption of maxillary incisors adjacent to impacted maxillary canines from small volume CBCT images by trained clinicians.

A secondary objective was to report the location and severity of root resorption.

Material and methods

This retrospective cross-sectional study was undertaken at Guy's and St Thomas' Hospital NHS Foundation Trust. This investigation was considered as a service evaluation by the Trust Governance Department (reference number: 12945) and ethical approval was not required. All images were taken within the Department of Dental Radiology at Guy's and St Thomas' Hospital NHS Foundation Trust between January 2019 and May 2022 and subsequently reviewed on the joint orthodontic – oral surgery clinic. Small volume CBCT images taken of patients with unerupted maxillary canines (unilateral and bilateral) for the purpose of diagnosis and multidisciplinary treatment planning were eligible for inclusion. Patients with syndromes and localized pathology such supernumerary teeth were excluded. The radiographic examination was carried out using a small field of view (FOV) CBCT machine (J. Morita.Mfg.Corp, Japan) with following exposure parameters: tube voltage of 70–90 kV, current of 2.0–4.0 mA and a scanning time of 17.5 seconds. The FOV was either 40 × 40 mm or 60 × 60 mm (diameter and height) depending on the area of interest. The CBCT image datasets were reconstructed and viewed using software provided by CBCT manufacturer (iDixel 3DX Version 1.8). DICOM images with the following field of view (FOV): 4 × 4 (pixel spacing 0.08 mm; window width [gray scale] 0–4000) and 6 × 6 cm (pixel spacing 0.125 mm; window width [gray scale] 0–2685) were reconstructed. The CBCT images were assessed at CBCT workstation using a desktop computer (Processor Intel® Core^{TM} i5-6500 CPU @ 2.50 GHz) with an Intel® HD Graphic 530 card and a colour liquid crystal display (54 cm) flat panel monitor. The contrast and brightness of each image were optimised to improve the image. Based on previous research, the following data variables were collected from each CBCT image/dataset and entered into a pre-piloted data collection sheet [10]:

- side of impaction (left, right or both);
- position of impacted canine: vertical (location of cusp tip in relation to the long axis of adjacent tooth subdivided into apical third, middle third, and coronal third of the root), transverse (measurement of canine cusp tip in relation to the buccal or palatal midline. The shortest distance from the canine cusp tip to the mid-palatal suture was measured perpendicular in mm on the axial CBCT scan) and sagittal (location of the canine in relation to adjacent teeth, classified as palatal, buccal or in the line of the arch, using CBCT slices perpendicular to the dental arch);
- proximity and position of the impacted canine to the adjacent tooth (apical third, middle third or cervical third of the root). Proximity was defined by $\leq$ 0.5 mm distance between two teeth [26];
- location of resorption affecting adjacent teeth (apical, middle third or cervical third of the root);
- degree of resorption was graded as suggested by Ericson and Kurol [27]: no resorption (intact root surface, the cementum layer may have been affected or lost), slight resorption (resorption up to half the dentine thickness), moderate resorption (resorption of the dentine midway to the pulp or more: the pulp lining remains intact) and severe resorption (resorption reaches the pulp);
- each canine was classified into complete root development with closed apex or incomplete root development with an open apex;
- follicle size was measured at the widest area of the follicle perpendicular to the crown of the impacted canine on coronal and axial CBCT scans. A distance greater than 3 mm was classified as enlarged [8];
- the presence of a deciduous canine was noted as existent and resorbed or existent and not resorbed;
- morphology of upper lateral incisor was classified as: missing, peg-shaped, and normal.

To ensure consistent interpretation, the primary orthodontic clinician (WLN) undertook a CBCT dento-alveolar level 1 (core training and referral) course and hands-on CBCT advanced level 2 (interpretation) course training provided by British Society of Dental and Maxillofacial Radiology. Both intra- and inter-reliability were assessed with another orthodontic clinician (AC) who undertook the same level of training and was involved in the data extraction process. Reliability was measured based on the assessment of ten CBCT images on two occasions (4-weeks apart). Subsequent data collection was then performed by the primary orthodontic clinician (WLN). Any discrepancies in image interpretation were recorded and discussed until a consensus was obtained between both orthodontic clinicians (WLN and AC). Both orthodontic clinicians were blinded to any radiological reports of the CBCT images.

Statistical analysis

A convenience sample was used based on consecutive patients who attended the joint orthodontic – oral surgery clinic. Descriptive statistics summarised the patient characteristics and clinicians' ratings for both intra- and inter-reliability (presence of resorption and severity on maxillary lateral incisor) were assessed using Cohen's kappa (< 0.2 = poor; 0.21–0.40 = fair; 0.41–0.60 = moderate; 0.61–0.80 = good; 0.81–1.00 = very good agreement). Tabulated data was used to describe associations between the presence of resorption on central and/or lateral incisors (no resorption/resorption) and patient characteristics (age, sex, root development, canine sagittal and vertical position, and morphology of lateral incisor) for prediction of resorption of adjacent teeth (central and lateral incisors). To account for individual-level clustering, univariable and multivariable generalised estimating equations (GEE) logistic regression models were fit between the outcome (no resorption/resorption) and selected study characteristics. An exchangeable correlation matrix and robust standard errors were used. All statistical analyses were performed using STATA software version 18.0 (Stata Corporation, College Station, Texas, USA).

Results

Within the study timeframe, eight hundred and twenty-four patients were assessed on the joint orthodontic – oral surgery clinic. Following screening of this sample, one hundred and twenty-seven patients initially met the study eligibility criteria. Five patients were further excluded due to the presence of additional pathology (supernumerary teeth) or poor image quality. In total, CBCT images of one hundred and twenty-two patients (42 males and 80 females) with 148 impacted maxillary canines were analysed. Intra-reliability Kappa scores for the assessors (WLN and AC) was 0.47 and 0.75 respectively. The inter-reliability Kappa between the two orthodontic clinicians (WLN and AC) was 0.61, which represents a good level of agreement.

In this sample, the majority of patients were under 18 years of age (71.6%). There were more females (68.2%) compared to males (31.8%). Frequently, the canine was located in the apical third (vertical) (58.8%), palatally impacted (62.2%), had a complete root with closed apex (90.5%) and the size of the crown follicle was between 0 < 3 mm (91.1%). The maxillary lateral incisor tended to have a normal appearance in the majority of cases (77.7%) (*table I*). The prevalence of root resorption on the maxillary central and lateral incisors was 14.9% and 38.5% respectively. The impacted canines were most likely in direct contact with the lateral (79.7%) and central (38.5%) incisors. For both these incisors, the impacted canine contacted both these teeth typically in the middle third region. The highest prevalence of resorption was detected in the apical third region of the lateral incisors (20.9%) with the severity of resorption graded as slight (10.1%), moderate (15.6%), and

TABLE I
Characteristics of participants and impacted canines (*n* = 148)

Characteristic	*n* (%)
Age	
< 18 years	106 (71.6)
> 18 years	42 (28.4)
Sex	
Male	47 (31.8)
Female	101 (68.2)
Canine vertical position (in relation to root of adjacent teeth)	
Apical third	87 (58.8)
Middle third	56 (37.8)
Coronal third	5 (3.4)
Canine sagittal position	
Palatal	92 (62.2)
Buccal	43 (29.1)
Median (line of arch)	13 (8.7)
Canine transversal position (mm)	
Mean (SD)	4.7 (3.1)
Canine side	
Right	78 (52.7)
Left	70 (47.3)
Root development	
Complete with closed apex	134 (90.5)
Complete with open apex	14 (9.5)
Follicle size (mm)	
0 < 3 mm	135 (91.1)
≥ 3 mm	13 (8.9)
Primary canine	
Present and resorbed	70 (47.3)
Present and non-resorbed	4 (2.7)
Absent	74 (50.0)
Morphology of lateral incisor	
Normal	115 (77.7)
Peg shaped	31 (20.9)
Missing	2 (1.4)

severe (12.8%) respectively. A similar trend was evident with the central incisors (*table II*). Palatally impacted canines were more likely to be in contact with the central incisor and lateral incisor. For both the central and lateral incisor, the site of direct contact with the palatal canine was the middle and apical third. More cases of resorption were evident with palatal canines compared to buccal canines with the apical third a common site of resorption for both central and lateral incisors (*table II*). The prevalence of root resorption on the first premolar and second premolar was 2.7% and 0.7% respectively. In two first premolars, the location of proximity/direct contact (palatal canines) was the apical and middle third and in one tooth, it was the cervical third. Resorption in first premolars occurred with palatal canines ($n = 3$) with only one case of resorption detected with a buccally impacted canine. The severity of resorption detected was graded as slight in two premolars and severe in one case with palatal canines. Only one first premolar underwent severe resorption associated with buccally impacted canine. In one second premolar was resorption detected associated with a buccal impacted canine. The location of proximity/direct contact was the middle third and the severity of resorption was classified as moderate.

The GEE univariable models showed no association between resorption and any of the predictors, whereas in the multivariable model, there was a weak association at the 10% level for age and root development in the multivariable model (*table III*).

Table II

Proximity/direct contact, location and severity of resorption of maxillary central and lateral incisor in relation to sagittal position of impacted canine (*n* = 148)

Adjacent incisor	Central incisor				Lateral incisor			
Canine sagittal position	Pal.	Buc.	Med.	*n* (%)	Pal.	Buc.	Med.	*n* (%)
Proximity/direct contact								
Yes	37	17	3	57 (38.5)	73	35	10	118 (79.7)
No	55	26	10	118 (79.7)	19	8	3	30 (20.3)
Location of proximity/direct contact (root)								
No	55	26	10	91 (61.5)	18	8	3	29 (19.6)
Apical third	4	11	2	17 (11.5)	23	13	4	40 (27.0)
Middle third	25	6	1	32 (21.6)	41	13	5	59 (39.9)
Cervical third	8	0	0	8 (5.4)	10	9	1	20 (13.5)
Location of resorption (root)								
No	79	34	11	124 (83.7)	57	24	10	91 (61.5)
Apical third	7	8	1	16 (10.8)	20	9	2	31 (20.9)
Middle third	6	1	1	8 (5.5)	15	6	1	22 (14.9)
Cervical third	–	–	–	0 (0.0)	0	4	0	4 (2.7)
Severeness of resorption								
No resorption	79	34	11	124 (83.7)	57	24	10	91 (61.5)
Slight resorption	7	1	1	9 (6.1)	9	5	1	15 (10.1)
Moderate resorption	4	3	0	7 (4.7)	14	7	2	23 (15.6)
Severe resorption	2	5	1	8 (5.5)	12	7		19 (12.8)

Table III

Univariable and multivariable GEE logistic regression derived odds ratios (OR) and 95% confidence levels for the effect of age, sex, root development, canine sagittal position, canine vertical position, and morphology of lateral incisor on predicting resorption of incisors (upper central and lateral incisors)

Predictor variables	Category	Univariable analysis	*P*-value	Multivariable analysis	*P*-value
				OR (95% CI)	
Age	< 18 years		Reference	Reference	
	> 18 years	0.57 (0.26, 1.21)	0.14	0.46 (0.19, 1.09)	0.08
Sex	Male		Reference	Reference	
	Female	0.86 (0.41, 1.78)	0.64	0.92 (0.42, 2.06)	0.86
Root development	Complete with closed apex		Reference	Reference	
	Complete with open apex	0.37 (0.09, 1.46)	0.16	0.26 (0.06, 1.06)	0.06
Canine sagittal position	Palatal		Reference	Reference	
	Buccal	1.39 (0.65, 2.9)	0.40	1.31 (0.56, 3.04)	0.53
	Median	0.92 (0.27, 3.13)	0.90	0.68 (0.18, 2.51)	0.56
Canine vertical position (in relation to root of adjacent tooth)	Apical third		Reference	Reference	
	Middle third	0.96 (0.47, 1.96)	0.92	0.93 (0.42, 2.07)	0.42
	Coronal third	0.72 (0.11, 4.59)	0.73	0.63 (0.11, 3.50)	0.61
Morphology of lateral incisor	Normal		Reference	Reference	
	Peg shaped	0.59 (0.25, 1.39)	0.23	0.55 (0.21, 1.45)	0.23

Discussion

The management of impacted canines can pose a significant clinical challenge. As part of the treatment planning, accurate identification of the location, position, and presence of associated pathology is paramount. CBCT images are considered the more contemporaneous diagnostic imaging technique, compared to conventional radiographs [28], because of greater accuracy. In all, 43.7% of treatment plans are changed as a result of the additional information provided by CBCT images compared to conventional imaging [25]. During treatment planning, a key consideration is the presence of root resorption affecting the adjacent maxillary teeth and detection of root resorption on incisors adjacent to impacted canines results in between 30–50% of treatment plans being altered [25,29]. Depending on the degree of resorption affecting the adjacent teeth such as lateral incisors, clinicians may opt to extract these teeth as opposed to healthy premolar units [30]. Conversely, following alignment of impacted canines, the long-term prognosis of resorbed maxillary lateral incisors has been reported to be favourable [30].

The primary findings of this study report that compared to maxillary central incisors and first and second premolars, the maxillary lateral incisors (38.5%) frequently undergo root resorption as a result of direct contact with the impacted maxillary canine. For lateral incisors, the typical site of resorption was the apical region (20.9%) with the severity of resorption graded as moderate (15.6%) and severe (12.8%). More cases of resorption were evident in females (68.2%) compared to males (31.8%). Additionally, a higher prevalence of root resorption was detected with palatally impacted canines with the apical third a common site of resorption for both central (10.8%) and lateral (20.9%) incisors and first premolars (2.0%).

The reported results are consistent with previous literature. Based on the assessment of CBCT images in primary studies, the maxillary lateral incisor in the vicinity of an impacted maxillary canine is the most common tooth to undergo root resorption. Within the literature, the reported prevalence ranges between 7.7–64.2% [10,13–17,31]. Quantitative analysis of the available evidence corroborates that the maxillary lateral incisor is the primary tooth affected (44.5%) with the apical third the most prevalent site for resorption (56.8%) [12]. We also report that the apical region was more commonly affected by resorption. However, in our sample, more impacted canines were assessed to be in contact with the middle third of the incisor root. On this basis, it could be assumed that this would be the most frequent site of resorption. It has been reported that the mesial aspect of the canine crown and its relationship to the incisor roots is a predictor of root resorption [24]. As this is cross-sectional assessment with no serial CBCT images taken, it is unclear when the canine initially contacted the incisor root or indeed if there was initial contact in the apical region followed by further movement toward the middle third of the root. Therefore, it can be postulated that the site of resorption does not always necessarily correlate with the assessment of canine crown position in relation to incisor root.

In the current study, the prevalence of root resorption was higher in females compared to males. This has been previously reported [10,11,13], although this should not be surprising as the incidence of impacted canines is higher in females [3]. The latter could be result of the fact that females tend to be higher seekers of orthodontic treatment than males [32], therefore impacted canines could be diagnosed more frequently during initial screening. It is also not uncommon to find higher rates of resorption associated with palatally impacted canines. In a review of 444 patients with 577 impacted canines, a higher incidence of resorption affecting both lateral and central incisors was reported with palatal canines compared to buccally placed cuspids [31]. The aetiology of incisor root resorption resulting from an underlying impacted maxillary canine is not fully understood. The dental follicle of the impacted canine has been postulated as a causative factor. However, this has been disputed in a CT evaluation of impacted canines. The authors concluded that the resorption of incisors is more likely to result as a both direct contact and pressure from the erupting canine [8]. Previous investigations have also reported the following variables as predicators of root resorption: the angle formed between long axis of impacted canine and adjacent lateral incisors [17], vertical position of the canine [10], position of the canine in the bone [10], area of contact with adjacent teeth [16], contact relationship [16], and rotation of the canine [16]. Although no significant predictors of root resorption were identified in the current study, a weak association was evident for age and root development. The observed difference noted between previous literature and the reported findings could be attributed to variation in the following: study sample sizes, diagnostic imaging utilised (2D and 3D imaging), heterogeneity of the analysed study samples relating to the position of the impacted canine and the reported incidence of root resorption. The latter is influenced by the reported assessor reliability and accuracy of detecting these lesions. Conversely, our findings concur with previous literature, which report that the sex of the patient and width of the dental follicle of unerupted impacted canines are not predictors or associated with the development of root resorption of incisors [8,31]. Although not statistically significant, patients aged over 18 years and patients with complete and open apex were at lower odds of resorption of incisors. Regarding the apex development, this is in accordance with the findings of Lai et al. [10] who reported a higher prevalence of root resorption when there was complete root development of the impacted canine with a closed apex. Regarding age, the patients under the age 18 years had a higher risk of root resorption. This could be attributed to the bias towards patients under the age 18 in the observed sample.

From a clinical perspective, the findings of this study can influence the clinical management of patients who present with an impacted maxillary canine. For instance, it would be prudent to undertake the appropriate special investigations to detect any evidence of root resorption of the adjacent incisors. For the alignment of palatally impacted canines causing root resorption of maxillary incisors, the initial orthodontic mechanics should be aimed at retracting the crown of the impacted canine distally away from the root surfaces of the incisors [33]. This approach reduces the risk of inducing unwanted rotations, further resorption of the incisor, and introducing a mechanical obstruction, which could slow optimal canine movement [33]. Once this has been achieved, then the vector of traction can be redirected to move the maxillary canine towards the line of the arch.

Although a sample and power calculation was not undertaken, a convenience sample was used, and the precision of the estimates communicated by the reported 95% confidence intervals. A limitation of the current investigation is potential selection bias, as the impacted canine cases were identified from a clinic, which specifically manages these cases. As a result, the reported incidence and severity of resorption affecting adjacent teeth may represent an over-estimation. This may be further compounded by the fact that the number of cases with no resorption detected on the adjacent teeth was not reported. Additionally, nearly 30% of the sample were over the age 18 years and 90.5% of the sample had a completed root development. The risk of resorption of adjacent teeth is associated with advanced development of the impacted canine [11].

Only a moderate – good reliability was evident between the two orthodontic clinicians, which could affect the validity of the reported results. However, in the reporting of CBCT images, it is not unusual for inter-assessor variation to exist [10,22,23]. Additionally, intra- and inter-assessor reliability (presence of root resorption and severity) was only measured for the maxillary lateral incisor. This decision was based on the fact that the maxillary lateral incisor is the most common tooth to undergo root resorption due to an impacted canine [12]. Reassuringly, the inter-reliability Kappa score in the current study is comparable to the level of agreement reported in previous studies investigating root resorption on incisors [23]. To mitigate for potential error in the reported measurements, all study variables collected were pre-defined based on previous literature [10] and the orthodontic clinicians completed level 1 and level 2 CBCT training.

An alternative methodology could have been to compare radiologists CBCT reports versus the clinician assessment of the CBCT image. Within the literature, the retrospective analysis of radiologist CBCT reports of impacted canines has been previously undertaken [34]. However, this approach could be prone to bias as the reliability of the radiologist versus clinicians' assessment of CBCT images was not assessed.

Conclusions

This cross-sectional analysis of CBCT dataset images confirmed that maxillary lateral incisors (38.5%) are the most likely teeth to undergo root resorption in the presence of an impacted maxillary canine. Females were more affected and palatal canines are more likely to cause root resorption. Sex, canine sagittal and vertical position, and morphology of lateral incisor did not predict root resorption of maxillary incisors. However, a weak association was evident for age and root development. Clinicians should consider the extent, location and severity of resorption of adjacent teeth when planning treatment decisions and mechanics in cases of impacted maxillary canines.

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