

Location and severity of root resorption related to impacted maxillary canines: a cone beam computed tomography (CBCT) evaluation

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Background: The present investigation was designed to determine the location and severity of root resorption associated with impacted maxillary canine teeth using cone beam computed tomography (CBCT). A secondary aim was to identify possible influencing factors.

Methods: The radiological reports of 183 patients, radiographed with a small-volume CBCT focussed on the impacted maxillary canine teeth, were assessed. Eighty-five patients had resorption associated with the impaction. The CBCT image datasets were viewed to determine the location and severity of the lesions.

Results: A total of 110 impacted maxillary canine teeth resorbed 120 adjacent teeth, including 14 premolars and one permanent molar. The apical third and palatal surface were commonly involved. Fifty per cent of the resorptive lesions were mild, 20% moderate and 30% severe. There was no significant relation between age or gender on the number, location or severity of resorption. There was a statistically significant correlation between the number of impacted canine teeth and the number of teeth resorbed, as well as the tooth type and the surface involved in the resorption.

Conclusions: All root levels and surfaces of teeth associated with impacted maxillary canine teeth can be resorbed to different levels of severity. Neither age nor gender influences the number, location or severity of the resorption.

(Aust Orthod J 2015; 31: 49–58)

Received for publication: October 2014

Accepted: April 2015

Introduction

An impacted tooth is one which is unable to erupt as a result of either insufficient space in the dental arch, ectopic position of the tooth, or the presence of an obstruction such as a retained tooth, supernumerary or scar tissue.¹ Following third molars, permanent maxillary canines are the second most commonly impacted teeth, with a prevalence reported to be between 0.92 and 2.8%.^{2–5}

A significant consequence of an impacted tooth is the occurrence of pressure resorption of adjacent teeth. This is evident as a form of localised external root resorption in which excessive pressure from an

impacted or supernumerary tooth stimulates the process.^{6,7} The removal of the stimulating factor will halt the progression of resorption, after which repair is expected to occur.^{6,8} Usually there are no clinical signs or symptoms presenting at the time of diagnosis.^{9–12} The pulp normally remains vital; therefore, there is no indication for endodontic treatment, although this may subsequently be necessary if the impaction pressure compromises the tooth's blood supply.^{6,7}

Dental resorption is particularly difficult to detect on plain radiographs in cases in which the hard tissue has been resorbed from the buccal or palatal root aspect.^{5,13,14} Furthermore, the resorptive process is

sterile, and so plain-film radiography is unlikely to demonstrate radiolucent areas, which would be likely if the resorption was infective in nature.⁷

The identification and prevalence of resorption related to an ectopic maxillary canine has been variously estimated at 0.6–0.8% or 48%, using plain-film radiography or conventional (medical) computed tomography (CT), respectively.^{5,12,15} CBCT-based studies suggest a higher incidence.^{16–18} Presently, small volume CBCT has become the imaging apparatus of choice for the localisation of impacted maxillary canines and the assessment of associated sequelae.^{16–21}

The aims of the present investigation were to determine the location of resorption in permanent teeth associated with impacted maxillary canines, and determine its severity in the axial plane, using small-volume CBCT.

Materials and methods

Radiographic examination and assessment of images

This retrospective cross-sectional investigation was reviewed and approved by Guy's and St Thomas' Hospitals NHS Foundation Trust Research and Development office. The study examined small-volume CBCT scan dataset images of consecutive subjects who had been referred for radiographic examination of their impacted or ectopically erupting maxillary canines. The subjects were referred to the Department of Dental Radiology, King's College London Dental Institute, between February 2008 and December 2011, for the purposes of diagnosis and treatment planning. The radiological reports, which were prepared by radiology consultants who were registered specialists in dental and maxillofacial radiology in the UK, were accessed to verify the presence of resorption for each CBCT scan dataset.

The radiographic examinations were performed with a small-volume CBCT unit (3D Accuitomo 80, J. Morita Manufacturing Company, Kyoto, Japan) whose exposure parameters were a tube voltage of 70–90 kV (based on subject size), a tube current of 3.0–4.0 mA and scanning time of 17.5 seconds. The field of view (FOV) was either 40 × 40 mm or 60 × 60 mm (diameter and height) depending on the size of the region of scanning interest.

The CBCT image datasets were reconstructed and viewed using software provided by the CBCT manufacturer (i-Dixel-3DX Version 1.8, J. Morita Manufacturing Company, Kyoto, Japan) at the CBCT workstation consisting of a desktop computer (Optiplex 745, Dell, Berkshire, UK) with a graphic card (Matrox Parhelia-LX Matrox Millennium P series, Matrox QID LP PCIe, Matrox Graphics Incorporation, Quebec, Canada) and a colour liquid crystal display 54 cm flat panel monitor (resolution 1600 × 1200 pixels, EIZO Nanao Corporation, Ishikawa, Japan). Image reconstructions were made to produce contiguous slices in increments of 0.64–1.0 mm in the axial, sagittal and coronal planes. The contrast and brightness for each image dataset was optimised to improve image quality, following which the scan volume was scrolled in each plane until an image slice was identified that best displayed the magnitude of the resorption.

The following variables were analysed by one examiner (EJD) for each CBCT image dataset following training and calibration that confirmed high-level intra-examiner agreement:

1. Type of impaction: unilateral, bilateral.
2. Side of the impacted tooth: unilateral right or left, bilateral.
3. Number of teeth resorbed.
4. Type of tooth/teeth resorbed.
5. Location of the impaction resorption relative 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 the impaction resorption relative to the affected surface: mesial, distal, buccal, palatal, mesio-palatal, disto-palatal, mesio-buccal, disto-buccal.
7. Degree (severity) of resorption, assessed in the axial plane, using a previously established classification.²²

As this study was only investigating cases already diagnosed with resorption using only CBCT scan datasets, those scans demonstrating teeth that would fall into the grade 1 category, defined as 'intact root surfaces, except for loss of cementum', were not considered. The remaining categories were used:

- Grade 2: slight resorption. Up to half of the dentine thickness to the pulp.

Table I. Descriptive data regarding gender, age, and distribution of impacted maxillary canine teeth.

Gender	Number of patients (%)	Age			Number of impacted maxillary canine teeth		
		Range	Mean	SD	Unilateral		Bilateral
					Right	Left	
Female	60 (70.59)	9–60	18.1	10.3	26	17	17
Male	25 (29.41)	11–54	18.4	10.8	11	6	8

Table II. Demographics of subjects experiencing multiple resorbed teeth.

Patient	Gender	Age (years)	Impacted tooth/teeth*	Resorbed teeth*
1	M	14	13,23	21,22
2	M	15	13,23	12,22
3	F	12	13	11,12
4	F	16	13,23	12,22
5	M	13	23	22,24
6	F	14	13,23	11,21
7	M	11	13,23	14,24
8	F	12	23	21,22
9	M	28	13,23	12,22
10	F	11	13,23	12,22,24
11	F	14	13,23	12,22
12	F	29	13,23	11,12,22
13	F	13	13,23	11,12,22
14	F	16	13,23	11,12,22
15	F	13	23	21,22
16	M	17	13,23	12,22
17	M	15	23	21,22
18	F	19	13	12,14
19	M	44	23	21,22
20	M	11	13	12,14
21	M	15	13	12,14
22	M	16	13	11,12
23	F	25	13,23	12,22
24	F	13	13,23	21,22
25	F	12	13	21,22
26	F	14	23	21,22
27	F	13	13	11,12
28	F	15	13,23	11,12,21,22
29	F	12	13,23	12,22

*FDI notation

Table III. Distribution of resorption lesions relative to root level.

Affected tooth	Location of resorption relative to root level (number)						Total number
	Apical 1/3	Apical & middle 1/3	Middle 1/3	Middle & cervical 1/3	Cervical 1/3	Apical, middle & cervical 1/3	
Central incisor	11	6	9	1		1	28
Lateral incisor	42	14	17		3	1	77
First premolar	11	1	1	1			14
First permanent molar			1				1
Total (%)	64 (53.33)	21 (17.5)	28 (23.33)	2 (1.67)	3 (2.5)	2 (1.67)	120 (100)

- Grade 3: moderate resorption. Half way to the pulp or more; the pulp is covered with dentine.
- Grade 4: severe resorption. The pulp is exposed.

Statistical analyses

Statistical analyses were performed using Stata 12.1 (StataCorp, College Station, TX, USA). For all tests, the significance level was set at $\alpha = 0.05$. Intra-examiner agreement was assessed using unweighted and weighted kappa, Stuart-Maxwell test and intra-class correlations. Pearson χ^2 was used to determine if there was any relationship between gender on the probability of unilateral or bilateral impaction, and the side of impaction on the frequency of resorption. A one-way analysis of variance determined if there was a relationship between age and the location or severity of resorption. The Kruskal-Wallis test assessed if there was a relationship between gender and the location or severity of resorption. Poisson regression, a model for analysing count data, was used for examining any relationship between age and the number of impacted canine teeth, on the number of resorbed teeth. The exact permutation test was used to determine if the type of tooth had any relationship with the location or degree of encountered resorption.

Results

One hundred and eighty three subjects – 129 females and 54 males with a mean age of 18.1 and 18.4 years respectively – were identified as having received a small-volume CBCT scan related to an impacted maxillary canine. Of these, 85 subjects (46.5%) comprising 60 females and 25 males, with an age range of 9–60 years (Table I), had a total of 110 impacted maxillary canine teeth which caused resorption lesions

in 120 adjacent teeth. The resorbed teeth comprised 28 (23.3%) central incisors, 77 (64.2%) lateral incisors, 14 (11.7%) first premolars and one (0.8%) first permanent molar (FPM).

Twenty-nine subjects – 18 females and 11 males with an age range of 11–44 years – presented with multiple resorbed teeth (Table II). Thirteen subjects (seven females and six males) had unilateral impactions and none of these subjects had more than two resorbed teeth. Sixteen subjects (11 females and five males) had bilateral impactions, of which 11 had two resorbed teeth, four subjects had three resorbed teeth and a single subject experienced resorption of all maxillary incisors. No male had more than two resorbed teeth, regardless of the type of impaction. Fifteen of the 25 subjects with bilaterally impacted canine teeth had resorptive lesions attributable to a single impacted canine.

All root aspects were susceptible to resorption (Table III). The effects could be limited to a single root third (Figures 1A–C), with the highest incidence noted at the apical third. Occasionally, the resorptive effects extended to involve multiple root thirds (Figures 2A–C). Resorptive lesions were seen to affect all root surfaces (Table IV), but the palatal surface was most frequently resorbed in over 50% of the affected teeth. The lesions varied greatly in their severity (Table V).

Despite the large age range of the subjects, there was no significant correlation between age and the number of teeth resorbed, the location or severity of the resorption lesions. Similarly, there was no significant relation between gender and the number, location or severity of the resorption lesions. However, there was a significant relationship between the tooth type and the surface affected by the resorption ($p = 0.02$). Teeth mesial to the impacted canine were frequently



Figure 1. (A) Axial; (B) sagittal; (C) coronal views of a patient with impaction resorption of the upper left permanent lateral incisor tooth due to impacted upper left permanent canine tooth; the apical third of the palatal surface has been resorbed to a slight degree (grade 2).

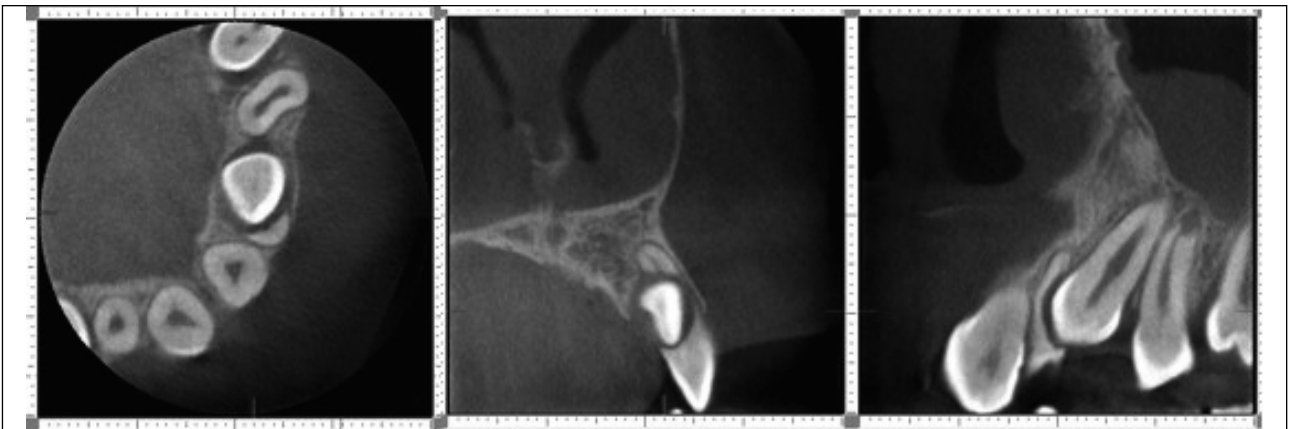


Figure 2. (A) Axial; (B) sagittal; (C) coronal views of a patient with impaction resorption of the upper left permanent lateral incisor tooth due to impacted upper left permanent canine tooth; the apical, middle and cervical thirds of the disto-palatal surface have been resorbed and the pulp has been exposed (grade 4).

resorbed on their palatal surface, whereas distally located teeth were frequently resorbed on their mesial surface. The site of impaction, whether in the right or left maxilla, had no significant effect on the incidence of the resorption lesions, with no significantly greater numbers of teeth resorbed on one particular side. A cumulative distribution function and Poisson's regression analysis demonstrated that a larger number of resorbed teeth were associated with bilaterally impacted canines, and so the number of impacted canines had a significant effect on the number of teeth resorbed ($p = 0.02$). There was no significant effect of gender on the probability of unilateral or bilateral impaction.

Discussion

This retrospective, cross-sectional study investigated the location and severity of the resorption of teeth

associated with impacted maxillary canines using small-volume CBCT.

A statistically significant association was found between bilaterally impacted canines and a larger number of teeth affected by resorption. Of the study population, 18.8% had bilaterally impacted canines that caused multiple tooth resorption. However, not every bilaterally impacted tooth caused resorption as 15 subjects with bilaterally impacted canines had resorption attributable to only a single impacted tooth.

Several previous investigations have examined the presence of resorption of adjacent teeth in relation to impacted maxillary canines using 3D radiography (Table VI).^{12,14-18,22} CBCT imaging may detect greater numbers of associated smaller resorption defects due to higher image resolution. Consequently, it is possible that CT studies may produce false negative findings and this may explain the proportionally lower number

Table IV. Distribution of resorption lesions relative to root surface.

Affected tooth	Location of resorption relative to root surface (number)								Total
	Mesial	Distal	Buccal	Palatal	Mesio-palatal	Disto-palatal	Mesio-buccal	Disto-buccal	
Central incisor		6	2	14	3	2		1	28
Lateral incisor	6	15	13	27	1	8	1	6	77
First premolar	7	1		3	3				14
First permanent molar	1								1
Total (%)	14 (11.67)	22 (18.33)	15 (12.5)	44 (36.67)	7 (5.83)	10 (8.33)	1 (0.83)	7 (5.83)	120 (100)

Table V. Distribution of degree (severity) of resorption lesions.

Affected tooth	Degree of resorption (number)			Total
	Slight	Moderate	Severe	
Central incisor	10	8	10	28
Lateral incisor	42	16	19	77
First premolar	8		6	14
First permanent molar			1	1
Total (%)	60 (50)	24 (20)	36 (30)	120 (100)

Table VI. Studies using 3D radiography to investigate the presence of resorption of adjacent teeth in relation to impacted maxillary canine teeth.

Author	Imaging type	Total patients (number)	Total impacted maxillary canine teeth (number)	Resorbed teeth (number)				
				Central incisor	Lateral incisor	First premolar	Second premolar	First permanent molar
Preda et al., 1997 ¹⁴	CT	19	29	2	6	-	-	-
Ericson and Kuroi, 2000 ¹²	CT	107	156	14	58	-	-	-
Ericson and Kuroi, 2000 ²²	CT	12	N/A	-	16	-	-	-
Walker et al., 2005 ¹⁶	CBCT	19	27	3	18	1	-	-
Liu et al., 2008 ¹⁷	CBCT	210	175	49	56	-	-	-
Cernochova et al., 2011 ¹⁵	CT	255	334	7	40	16	-	-
Lai et al., 2013 ¹⁸	CBCT	113	134	7	34	6	1	-
Present study	CBCT	85	110	28	77	14	0	1

- not studied/reported

of resorbed teeth reported in CT studies compared with CBCT studies. Ericson and Kuroi suggested that transverse CT scans found no root resorption on 355 incisors in the 107 subjects studied.¹² It may be surmised that the image resolution of 0.3 mm may have been insufficient to allow for the detection of root resorption, despite the enlargement (zooming factor) of $\times 1.5$. Therefore, it is possible that there may have been resorptive lesions that were not identified. The

sensitivity of CBCT over CT may be highlighted by comparing the resorption incidence detected in two different studies.^{14,16} Both studies assessed the same total number of patients (19) and approximately the same numbers of impacted maxillary canines (29 and 27 respectively). The similarities do not continue, as the CT study detected resorption in only eight teeth, whereas the CBCT study detected resorption in 22 teeth, including a premolar.

Table VII. Studies using 3D radiography to investigate the severity of resorption of adjacent teeth related to impacted maxillary canine teeth.

Author	Imaging type	Total patients (number)	Resorbed tooth	Degree of resorption (number)			
				None	Slight	Moderate	Severe
Ericson and Kuroi, 2000 ¹²	CT	107	Central incisors	142	5	3	6
			Lateral incisors	94	18	5	35
Ericson and Kuroi, 2000 ²²	CT	12	Lateral incisors	1	3	3	10
Liu et al., 2008 ¹⁷	CBCT	175	Central incisors	160	17	20	12
			Lateral incisors	150	32	13	11
Cernochova et al., 2011 ¹⁵	CT	255	Central incisors	-	-	-	7
			Lateral incisors	-	-	-	40
			First premolars	-	-	-	16
Lai et al., 2013 ¹⁸	CBCT	113	Central incisors	-	3	1	3
			Lateral incisors	-	12	5	17
			First premolars	-	3	-	3
			Second premolars	-	1	-	-
Present study	CBCT	85	Central incisors	-	10	8	10
			Lateral incisors	-	42	16	19
			First premolars	-	8	0	6
			First permanent molar	-	0	0	1

- not studied/reported

Regardless of the type of imaging unit used, the lateral incisors are the most frequently affected teeth in relation to impacted maxillary canines, whereas the resorption of other teeth is rarely reported.^{5,12,14-18,22-25} Liu et al. identified a resorption rate of 23.4% for central incisors and 27.2% for lateral incisors.¹⁷ The present study found a comparable incidence between central incisors (23.3%); however, the resorption incidence for lateral incisors was greater (64.2%). The present study also found resorption affecting 14 first premolars (11.7%) and one FPM (0.8%). The reported incidence of resorption of premolar teeth is very low, which suggests that their involvement in canine-initiated resorption is uncommon.

The location of resorption may be described according to the root surface and level affected. The majority of lesions are located in the apical third of the root, and the cervical third is the least commonly involved area.^{12,15,18} Two earlier investigations identified the next most commonly affected location as the middle third.^{12,18} The result of the current study is in agreement with the previous site pattern described by Cernochova et al., who found that after the apical third, the next common site of resorption was the apical and middle root third level.¹⁵ In the current study, 25 teeth (20.8%) had resorption lesions

involving at least two root levels; two teeth (one lateral and one central incisor) had resorption affecting the apical, middle and cervical thirds.

It is considered insufficient to limit the description of root resorption to solely affect a single surface as 3D radiography techniques have helped with the visualisation of all tooth surfaces. Seventy per cent of the affected teeth involved the buccal and palatal root surfaces, which are considered harder to detect on plain films. One tooth, a lateral incisor, was found to have mesio-buccal surface resorption, and seven teeth (three central incisors, one lateral incisor and three first premolars) had mesio-palatal resorption. Ericson and Kuroi reported that the disto-palatal surface was the most common site for root resorption,¹² whereas the present study found the palatal surface was significantly involved. It was impossible to undertake a full direct comparison of the present results concerning the surface resorbed, with those of other studies because of the high variability and differences in the categories used to classify previous findings.

Several studies have investigated the degree of resorption of teeth adjacent to impacted maxillary canines (Table VII). In the present study 20% of the resorptive lesions were moderate in nature as

the lesions extended half way to the pulp or more, whereas 30% of the resorbed teeth presented with pulp exposure. Pulpal exposure was detected in 24.7% of resorbed lateral incisors. This almost matches the incidence observed in the CBCT investigation by Liu et al., who found 19.6% of resorbed lateral incisors had pulpal exposure, although the applied classification system was modified so that teeth with a moderate degree of resorption were also defined as those which had the lesion limited to a single third of the root level.^{17,22} Those teeth rated as having a severe degree of resorption also had to display involvement of more than a third of the root level, in addition to a pulpal exposure.^{17,22} Additional studies have reported a higher incidence of grade 4 resorption detected in lateral incisors.^{12,18,22}

In the assessment of the severity of the resorption, it was decided to exclude the grade 1 category suggested by Ericson and Kurol.²² The present study investigated teeth diagnosed with resorption and the currently available small-volume CBCT units do not allow accurate visualisation and detection of cementum loss. The diagnostic accuracy (A_z) value has been shown to be highest when a small FOV (6×6 cm) and voxel size of 0.125 mm^3 are used.²⁶ A thickness of 0.125 mm is equivalent to $125 \text{ }\mu\text{m}$. Cementum, which is formed gradually throughout life, has varying thickness at different root levels, from $10\text{--}15 \text{ }\mu\text{m}$ at the cervical level to $10\text{--}50 \text{ }\mu\text{m}$ at the root apices and inter-radicular areas.²⁷ Consequently, the use of the grade 1 category is more appropriate to the histological assessment of resorption.

The long term fate of resorbed teeth is variable. A follow-up study of 48 resorbed incisors in 35 patients who had surgical exposure and alignment of their impacted canines reported that 33.3% of the resorbed incisors were extracted to facilitate orthodontic treatment. The resorption worsened in 14.6% of incisors, remained stable in 25%, and 27.1% exhibited signs of repair. All of the surviving incisors were deemed clinically vital.²⁸ Furthermore, the damage caused by resorption might produce debilitating and permanent effects that would reduce the reparative potential of the pulp if a subsequent insult, such as orthodontic tooth movement, was applied.^{29,30} One long-term study reported a patient who had exposure and alignment of an impacted canine as part of fixed orthodontic treatment and who subsequently required endodontic treatment on a tooth affected by

worsening resorption associated with the impaction.²⁰

Although functional, teeth with severe root resorption and reduced intra-alveolar root length have been purported to present with increased mobility. However, long-term follow-up studies have suggested that this is not necessarily the case.^{20,31}

The present study was not intended to assess the influence of radiological findings on treatment decisions or outcome, or determine the position of the impacted canine in the alveolar process. Additionally, almost half of the study sample was derived from external referrals to the Dental Institute and therefore it was not possible, nor was it an objective, to compare the image datasets with plain films originally taken by the referrer.

The clinical management of a patient demonstrating impaction resorption of their adjacent teeth is dictated, in the first instance, by the patient's preference following an explanation of the diagnosis, possible treatment options and their likely outcomes. If a patient declines treatment, it is important that they be informed of the presence and severity of the resorptive lesion(s) and advised that the process would be expected to continue should the impacted maxillary canine remain in situ. The patient should be encouraged to visit their dentist routinely in order to review the effect of the root resorption on the overall function of the dentition.

In those patients who wish to embark on a course of orthodontic treatment and who lack space in their dental arch for complete alignment, a clinical understanding of the integrity of the radicular tissues may be helpful in order to determine the most appropriate extraction pattern. This present study has confirmed the value of CBCT imaging in the visualisation of resorption on surfaces not normally detected with 2D imaging, as well as providing an assessment of the severity of the resorption. Accordingly, clinicians may choose elective extraction of a lateral incisor affected by severe resorption instead of a premolar that may have sound radicular tissues and is considered to have a better long-term prognosis.^{20,32} It is also important to appreciate that the surgical exposure and orthodontic alignment of an impacted canine has been shown to be associated with the loss of periodontal support of the adjacent teeth, and predisposes to an increased risk of future complications, such as the ultimate loss of the resorbed teeth subsequent to trauma or periodontal disease.^{20,33}

If a patient has resorption affecting a tooth but elective extractions to facilitate alignment are not considered necessary, it may be reasonable to maintain the resorbed tooth in the short-term for aesthetic, space/bone maintenance and masticatory purposes. The patient should be advised that the tooth is at risk of future loss and plans should be prepared for the subsequent prosthodontic replacement of the tooth should the need arise.

The additional information obtained from CBCT examinations delivers a better understanding of the patient's clinical presentation, which enables more accurate diagnoses and the completion of appropriate short-, medium- and long-term mechanical treatment aims/plans.

Conclusions

1. Small-volume CBCT is a useful tool in the localisation and grading of root resorption related to impacted maxillary canines.
2. There is a significant correlation between the number of impacted canines and the number of resorbed teeth as well as the tooth type and the affected surface.
3. Age was not found to be a statistically significant factor in the number, location or severity of the resorptive lesions.
4. Lateral incisors were most likely to experience resorption in relation to an impacted maxillary canine, with the palatal surface and the apical third frequently involved.
5. CBCT can detect slight, moderate or severe degrees of resorption.

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