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Research Article

THREE-DIMENSIONAL LOCALISATION OF IMPACTED MAXILLARY CANINES AND ROOT RESORPTION OF NEIGHBOURING INCISORS: A CBCT STUDY

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ABSTRACT

Permanent maxillary canines are the second most frequent impacted teeth after third molars. Therefore precise detection of an impacted maxillary canine is the first step of management. The aim of this study was to quantify the spatial relationship of impacted maxillary canines located on either both sides or on one side by using 3-dimensional (3D) volumetric imaging. A total of 53 impacted canines from 42 patients were studied, including 11 bilateral impactions. The images were taken using NewTom GiANO cone beam computed tomography (CBCT) machine. Locations of impacted canines were assessed in relation to neighbouring structures. Linear and angular measurements were taken with the 3D software. Root resorption of adjacent incisors was also investigated. Among the studied impactions, 79.2% were impacted palatally and 11.3% buccally. Lateral incisors (30.2%) were the teeth most affected by resorption than central incisors (3.8%). The correlation between contact/proximity and resorption of incisors was highly significant. No significant relationship was observed between the occurrence of root resorption and a widened dental follicle. On the affected side, there was clinical decrease in width of the alveolus than normal side. The location of impacted maxillary canines varies greatly in 3 planes. Thus CBCT provides accurate information about location of the impacted canine and prevalence, degree and their association with root resorption of neighbouring teeth. This information is of great importance for orthodontists and surgeons for accurate diagnosis and interdisciplinary treatment planning.

INTRODUCTION

Impacted canines are commonly found in orthodontic practice. In pathological terms, impacted teeth can be defined as a state where a tooth remains embedded in the oral mucosa or bone past its normal eruption period. However, the clinical definition of impacted teeth can be broadened to include teeth that are predicted to undergo abnormal eruption, even before its normal eruption period, due to position of tooth germ, tooth shape, direction of eruption, and available space (Kim *et al.,* 2012). Permanent maxillary canines are the second most frequent impacted teeth after third molars with 2% prevalence rate in the general population since they have an extended development period deep in maxilla, have large root surface area to develop and a long tortuous path of eruption compared to other teeth (Bedoya MM and Park JH, 2009). Also, existence of additional teeth in the eruption path is an important factor for delaying maxillary canines from eruption (Inspection, 2000).

Localization of an impacted tooth necessitates an accurate investigation of the adjacent anatomical structures. Contacts between impacted tooth and adjacent teeth roots may have resorptive impacts on both the impacted tooth and the adjacent teeth (Preda *et al.*, 1997). Therefore precise detection of an impacted maxillary canine is the first step of management. Early detection of impacted maxillary canines could reduce the time, complexity, and cost of the treatment as well as its complications (Kim *et al.,* 2012).

Although accurate diagnosis and localization of the impacted maxillary canine especially investigating root resorption requires three-dimensional (3D) imaging, such techniques are expensive and expose the patient to a high dosage of radiation (Ericson and Kurol, 1988). Cone Beam Computed Tomography (CBCT) is a new imaging technique that recently became increasingly important in treatment planning and diagnosis in dentistry. This technique offers undistorted 3D images of

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patients' dentofacial skeleton without exposing them to high dosages of radiation compared to conventional CT scans (Walker *et al*., 2005; Alqerban *et al*., 2011; Kau *et al*., 2005).
The aim of this study was to quantify the spatial relationship of impacted maxillary canines located on either both sides or on one side by using 3-dimensional (3D) volumetric imaging. The following factors were analyzed: type of impaction, proximity to adjacent structures, resorption of incisors, follicle size and alveolar width, linear and angular measurements of impacted maxillary canines with reference lines.

MATERIALS AND METHODS

Patients

The study was carried out on the patients visiting the out-patient section of the Department of Orthodontics and Dentofacial Orthopaedics, Government Dental College & Hospital, Shereen Bagh, Srinagar. CBCT scans were taken for orthodontic reasons to correctly locate the maxillary impacted canine with or without suspicion of resorption of neighboring teeth. Patients with combined incisor and canine impactions, craniofacial anomalies and syndromes, cleft lip and cleft palate patients were not included in this study. A total of 42 patients (27 female, 15 male) were selected satisfying the above conditions. These clinical situations were considered as a single group. A total of 53 impacted canines were studied, including 11 bilateral impactions, 17 right unilateral and 14 left unilateral impactions. The mean age of the patients was 21.2 years (range: 13-30 years, SD ± 5.09 years) with majority of subjects being 14-19 years.

Methods

The data was obtained using the NewTom GiANO NNT Scanner. All the scans were taken using the same machine by the same operator. The NewTom GiANO Scanner is based on a cone-beam technique that uses X-ray emissions efficiently, thus reducing the dose absorbed by the patient. The operating parameters were set at 3mA and 90kV, dose of 80-100 µSv and the scan time of 9 seconds. All CBCT images were taken using a limited dentoalveolar field of view (FOV: 11cm×8cm, 8cm×8cm and 8cm ×5cm).

Imaging data was analyzed with the software provided by the manufacturer (NewTom 9000 Version 3. 10). The data was reconstructed in slices, and examined slice by slice in all three dimensions (sagittal, coronal and axial) on 1:1 scaled images using the provided software. The following analysis and measurements were performed for every included subject:

Type of impaction (buccolingual crown location of impacted canine in relation to neighbouring teeth, mostly lateral incisors): It was classified as *buccal*, *palatal* and *apical* position. It was assessed using sagittal and/ or axial view (Fig. 1).

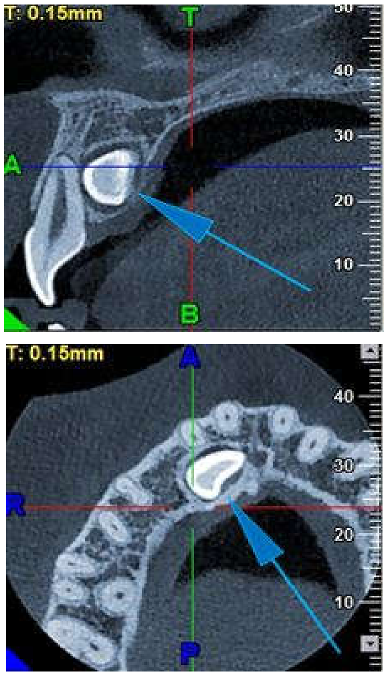

Fig 1 Representative example of a sagittal and axial CBCT scans exhibiting a palatally located impacted canine.

Root resorption of incisors

Resorption was defined as loss of dentine with or without involving pulp. It was assessed using axial view (Fig. 2)

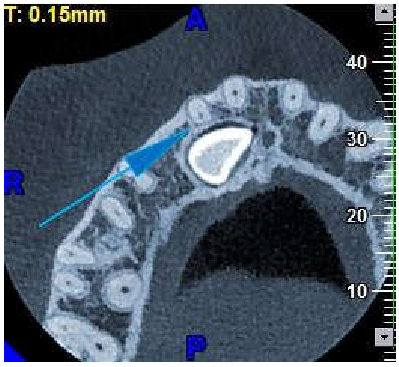

Fig 2 Representative example of root resorption on a right lateral incisor in axial view

Proximity of the impacted canine to the lateral and central incisors (Yes/No): This was measured as the shortest distance between the impacted canine and the incisor (Fig. 3). Contact was defined by ≤ 0.5 mm distance between the two teeth.

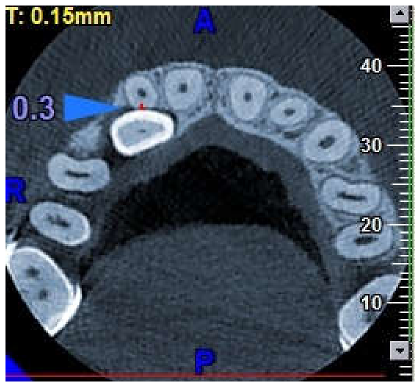

Fig 3 Proximity between impacted canine and lateral incisor in axial view

Follicle size: It was measured at the widest area of the follicle perpendicular to the crown of the impacted canine in axial CBCT slices. Distances greater than 2 mm were considered to be an enlarged follicle (Fig. 4) (Ericson *et al*., 2001)

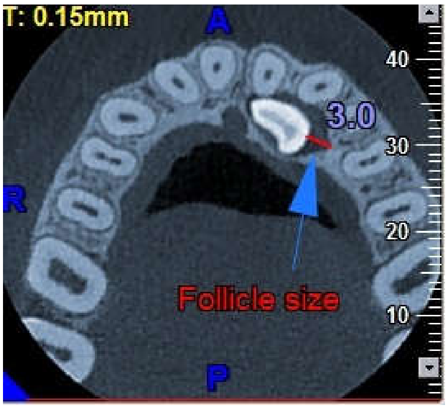

Fig 4 Follicle as measured in millimetres from crown to periphery of follicle (axial view).

Alveolar width in the area of the canine. It was measured both on the impacted side and on the normally erupted side. It was measured at the cervical level of the adjacent teeth of both left and right sides.

Location of Impacted Canine*:* This was determined from 3 views: *coronal* or *frontal*, *sagittal*, and *axial* or *horizontal*. Distances and angles were measured with the NewTom software provided by the manufacturer in these views.

Reference lines were created for assessment of location. The reference lines were *horizontal occlusal plane line* and a *vertical line bisecting the midline of the jaws*. All distances were measured perpendicularly from the cusp tip of the impacted tooth to the reference lines.

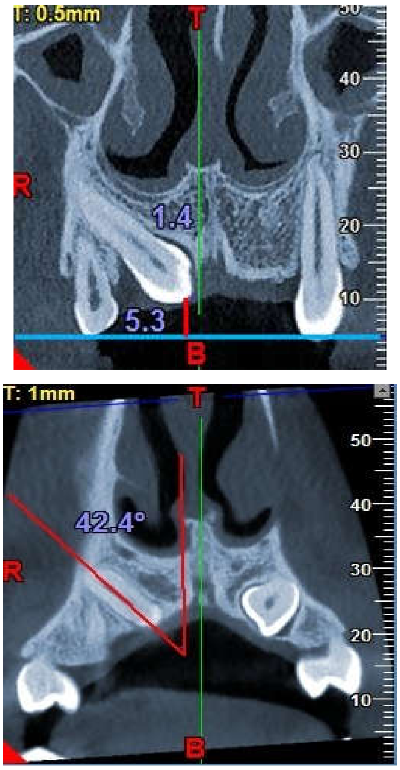

Fig 5 Example showing distance between impacted canine tip to occlusal plane and angle between impacted canine and midsagittal plane in coronal view.

The angles measured were the angles formed by the line bisecting the long axis of the tooth and the reference line.

From the coronal view, measurements taken were: distance from cusp tip of the impacted canine to the midline, distance from cusp tip of the impacted canine to the occlusal plane, angle of the impacted canine to the midline (Fig. 5) and angle of the impacted canine to the occlusal plane.

From the sagittal view, the measurements taken were: distance from the cusp tip of the impacted canine to the occlusal plane and angle of the impacted canine to the occlusal plane (Fig. 6).

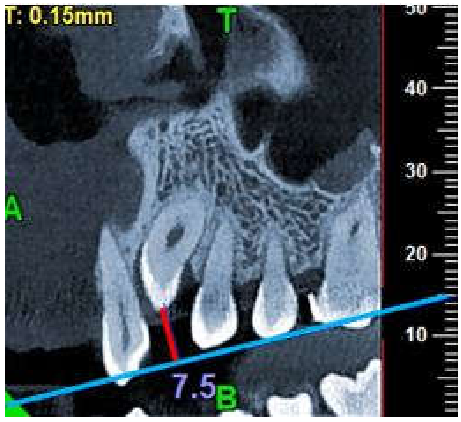

Fig 6 Example showing distance between impacted canine and occlusal plane in sagittal view

From the axial view, the measurements taken were: distance from the cusp tip of the impacted canine to the midline and angle of the impacted canine to the midline (Fig. 7).

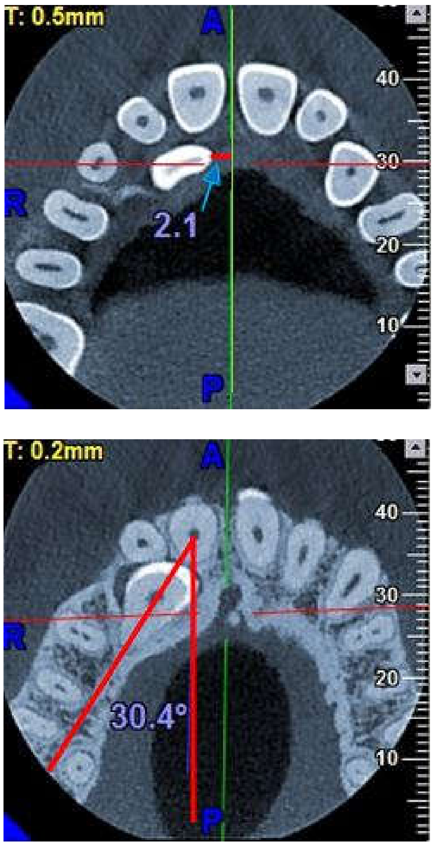

Fig 7 Axial view showing distance and angle between impacted canine and midline

Statistical analysis

The recorded data was compiled and entered in a spreadsheet (Microsoft Excel) and then exported to data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). Continuous variables were summarized in the form of mean and standard deviations and categorical variables were summarized as percentages. Chi-square test or Fisher's exact test, whichever appropriate, was used for comparison of categorical variables. A P-value of less than 0.05 was considered statistically significant. All P-values were two tailed.

RESULTS

In this study, a total of 42 patients with CBCT scans were enrolled, and 53 impacted canines were analysed. The mean age of the patients was 21.2 years (range: 13-30 years, SD ± 5.09 years) with majority of subjects being 14-19 years (Table 1). Of the 42 included patients, 15 (35.7 percent) were male and 27 (64.3 percent) were female (Table 2).

Table 1 Age distribution of studied patients

Age (years)	No.	%age	Mean ± SD (Range)
8-13	2	4.7	
14-19	16	38.1	
20-25	12	28.6	21.2±5.09
26-30	12	28.6	(13-30)
Total	42	100	

Table 2 Gender distribution of studied patients

Gender	No.	Percentage
Male	15	35.7
Female	27	64.3
Total	42	100

It is evident from the distribution of the impacted canine position (Table 3) that there were 42 palatally impacted canines (79.2 percent) to 6 buccally impacted canines (11.3 percent), which is a seven-fold greater prevalence for the palatal side. Of the 53 impacted canines, 5 were located apically (9.5 percent)

Table 3 Type of impaction with respect to adjacent teeth (lateral incisor)

Type of Impaction	No.	%age
Buccal	6	11.3
Palatal	42	79.2
Apical	5	9.5
Total	53	100

The lateral incisors were the teeth most affected by resorption and were more resorbed than the central incisors. On the 53 sides with ectopically positioned maxillary canines, 18 incisors were resorbed, which include 16 lateral incisors (30.2%) and 2 central incisors (3.8%) (Table 4). Resorption occured only on the lateral incisors on 16 sides, only on the central incisors on 2 sides, and on both incisors in none. No significant correlation between age, sex, and resorption was found.

Table 4 Incisor resorption associated with impacted canines

Resorption	Lateral Incisor		Central Incisor	
	No.	%age	No.	%age
Yes	16	30.2	2	3.8
No	37	69.8	51	96.2
Total	53	100	53	100

15 of the 37 lateral incisors with canine contact were resorbed, whereas only 1 of 16 laterals without canine contact was resorbed. The correlation between contact and resorption was highly significant (P-value = 0.021). 2 of the 7 centrals with canine contact were resorbed, whereas none of the 46 centrals without canine contact was resorbed, again showing a high correlation between contact and resorption (P-value = 0.015) (Table 5).

Table 5 Relationship of proximity of impacted canine with incisor root resorption

Resorption	Laterals		Centrals	
	Contact	No contact	Contact	No contact
Yes	15 (40.5%)	1 (6.2%)	2 (28.6%)	0 (0%)
No	22 (59.5%)	15 (93.8%)	5 (71.4%)	46(100%)
Total	37	16	7	46
P-value	0.021		0.015	

Approximately two-third of the impacted canine follicles examined were within normal limits (66.67%). The remaining cases (33.33%) were considered enlarged (> 2 mm). Follicle size varied from 0.5 mm to 3.8 mm, with an average of 1.76 mm. In two cases, the follicle was not detected. No significant relationship (P-value =0.40) was observed between the occurrence of root resorption and a widened dental follicle of the ectopic canine (Table 6 & 7).

Table 6 Follicle size in impacted canines

	Mean	SD	Range
Follicle size	1.76	0.738	0.5-3.8

Table 7 Relationship of follicle size with incisor root resorption

Follicle Size	Resorption		No Resorption		P-value
	No.	%age	No.	%age	
Within Normal Range	10	58.8	24	70.6	
Enlarged	7	41.2	10	29.4	**0.401**
Total	17	100	34	100	

From an axial view, the width of the alveolus at the cervical margin of erupted canine was measured and compared with the

Table 8 Width of alveolus measured (in mm) at the cervical margin of erupted canine and at the level of cervical margin of adjacent teeth on impacted canine side

Unilateral impacted canine, case no.	Width at cervical margin of erupted canine	Width at cervical margin on impacted side	Unilateral impacted canine, case no.	Width at cervical margin of erupted canine	Width at cervical margin on impacted side
1	9.3	6.5	18	9.6	8.1
2	9.6	7.2	19	9.3	7.3
3	10.5	8.5	20	9.2	7.0
4	10.2	8.3	21	9.9	8.1
5	9.5	7.5	22	10.0	6.2
6	9.5	7.3	23	10.2	7.6
7	12.3	10.2	24	9.1	7.2
8	10.6	7.8	25	9.4	7.8
9	10.1	9.2	26	9.9	7.6
10	9.8	8.1	27	9.7	6.5
11	9.6	8.0	28	10.6	8.2
12	9.3	7.5	29	10.3	6.6
13	11.5	8.1	30	9.9	7.4
14	9.2	7.9	31	9.4	7.8
15	9.8	5.8			
16	9.5	6.1	Average	9.9	7.6
17	10.6	7.3	SD	0.67	0.88

width of the alveolus of the impacted canine side at the level of the cervical margin of the adjacent teeth for the unilateral impacted canine cases. There was a clinical decrease in the width of the alveolus at the impacted canine side compared with the width of the alveolus of the erupted canine. The average widths of the alveolus were 9.9 ± 0.67 mm at the erupted canine cervical margin and 7.6 ± 0.88 mm on the affected side (Table 8).

The distances measured from the impacted canine to the midline and occlusal plane varied in the coronal, sagittal and axial views. In coronal view, averages for the distance of the cusp tip of the impacted canine to the occlusal plane and to the midline were 9.32 ± 4.04 mm (range: 0-16.5 mm) and 5.70 ± 3.49 mm (range: −1-12.9 mm), respectively. Only two impacted canines crossed the midline. The distance from the cusp tip of the impacted canine to the occlusal plane averaged 9.11 ± 3.98 mm (range: 0-16.7 mm) in the sagittal view and to the midline averaged 5.96 ± 3.65 mm (range: 1.2-15 mm) in axial view. The greatest variation was found from the cusp tip of the impacted canine to the occlusal plane in the coronal and sagittal views.

Angular measurements showed that the angle between impacted canine and the midline, impacted canine and occlusal plane varied in the coronal, sagittal and axial views. In coronal view, average for the angle between long axis of impacted canine and occlusal plane was 122.22° ± 13.65 (range: 99.4° - 157°) and between long axis of impacted canine and midline was 30.54° ± 15.59 (range: −29° - 62.8°). In sagittal view, the angle between impacted canine and occlusal plane varied from 44° to 163° with an average of 135.16° ± 18.92. In axial view, angle between impacted canine and midline averaged 24.03° ± 17.22 (range: -21.5°-64.6°).

DISCUSSION

In recent literature, the prevalence of impacted maxillary canines varies from 1% to 3% (Preda *et al*., 1997 and Chaushu *et al*., 1999). Females seem to be more affected (Dachi and Howell, 1961 and Becker *et al*., 1981). In our study, there were more female subjects than male subjects resulting in a ratio of almost 2:1. Walker and co-workers speculate that the difference in genetics, as well as overall craniofacial growth and development between the two sexes, could be possible reasons for that finding (Walker *et al*., 2005). Another reason could be that girls and women seek orthodontic treatment more frequently than males, as a result are reported more often than females.

In European and North American samples, impacted maxillary canines were more often found to be located palatally (85-92.6 percent) as studied by Preda *et al* (1997) and Ericson and Kurol (1988). In our study sample, we also found a high prevalence of palatally impacted canines (79.2 percent) consistent with the findings of Preda *et al* (1997). In Asian samples, however, impacted canines were more often located buccally (45.2 percent) than palatally (40.5 percent) as reported by Liu *et al* (2008). Earlier study by Jacoby (1983) and Peck *et al* (1994) have shown that labial and palatal displacement of maxillary canines are different phenomena. Labial displacement is usually due to an inadequate dental arch space, whereas palatal displacement often occurs despite adequate arch space. The etiology of palatally displaced canines can be divided into local or genetic factors. Local factors, such as persistent deciduous canines, delayed eruptive pathways, and missing or anomalous lateral incisors contribute to the etiology, as described by Becker *et al* (1981). Differences between various studies with regard to prevalence and location of impacted canines may also be due to differences in patient selection.

The etiology of root resorption is still unclear. It has been postulated that enlarged dental follicles, as well as the pressure caused by an erupting tooth, may be responsible for root resorption of adjacent teeth (Marks *et al*., 1997). However, Ericson *et al* (2001) have concluded, based on a CT examination, that the dental follicle does not cause root resorption of permanent teeth. They concluded that resorption of the permanent maxillary incisor is caused by the physical contact between the incisor and the canine, and by direct pressure from the canine as a part of the eruption process. This study supports previous findings that there is a correlation between prevalence of root resorption of permanent teeth and proximity/contact of the impacted canine. In the present sample, 15 resorbed lateral incisors showed proximity/ contact with the impacted canine, as did 2 resorbed central incisors. Only one lateral incisor and no central incisor was resorbed without direct canine contact. Further our study found that there was an overall but not statistically significant tendency for enlarged canine follicles to occur together with root resorption.

Measurements made on different views showed that the distance from the cusp tip of the impacted canine to the midline of the jaws is relatively constant, whereas the distance from the cusp tip of the impacted canine to the occlusal plane varies widely. This indicates that impactions vary greatly, and there is no common mode of impaction. There is considerable variation in the inclination of the impacted canine; some are vertically impacted and others are horizontally impacted, with variations in between (Walker *et al*., 2005). The angular and linear measurements further show the spatial variations of the impacted canine in 3 planes. These variations yielded a picture for the three-dimensional relationship of the impactions relative to the adjacent dental arch, which was impossible to obtain simply by using conventional radiographs.

In a CT study analysing 12 patients with 17 impacted canines, Ericson and Kurol (2000) found that the ipsilateral lateral incisor was the tooth most commonly affected by root resorption (38 percent), followed by the ipsilateral central incisor (9 per cent). In our study, we found root resorption in 30.2 percent of the lateral incisors, 3.8 percent of the central incisors. Root resorption as a result of impacted canines seems to be a rapid, progressive process that almost always ceases once the impacted canine has been removed from the affected root area (Becker and Chaushu, 2005). Previous studies have shown that the amount of information obtained from three-dimensional analysis is significantly greater than from conventional periapical and panoramic radiography (Alqerban *et al*., 2011) and consequently this may have an influence on the treatment plan (Bjerklin and Ericson, 2006).

The proper treatment of impacted maxillary canines depends on various factors like general oral health, type of impaction, presence of spacing and crowding, open or conservative surgical procedure and associated complications such as resorption of adjacent teeth and cystic degeneration. Treatment alternatives include interceptive treatment, surgical exposure and orthodontic alignment, auto transplantation, or even extraction of the impacted canine (Peng *et al*., 2004; Oliver, 2002). For those impactions that should be removed or exposed, the comprehensive pictures in 3 planes provided by CBCT can assist surgeons in choosing the appropriate surgical approach, identifying the tooth that should be extracted, and reducing the amount of surgical trauma on the adjacent hard and soft tissues (Liu *et al*., 2008).

CONCLUSION

Resorption of the incisors is very difficult to detect and diagnose as it is asymptomatic in early stages of resorption. Impacted canine and the consequent root resorption if diagnosed at right time might reduce further complications during treatment and the presence or absence of root resorption will determine the treatment plan. More important, if signs of ectopic eruption are detected early, every effort should be made to prevent impaction and its consequences. Early intervention can spare the patient time, expense, more complex treatment and injury to otherwise healthy teeth. The severity of lateral incisor root resorption cannot be accurately judged from two-dimensional radiographs alone. Therefore, CBCT is a useful method for diagnosing the position, inclination, distance from adjacent structures, complications of impacted canines, and detection of incisor root resorption. Moreover, CBCT has smaller radiation dose compared to CT and overcomes the limitations of conventional radiography. Furthermore, this method has a significant impact on diagnostic and therapeutic interventions.

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