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Localization of impacted maxillary canines and observation of adjacent incisor resorption with cone-beam computed tomography

Deng-gao Liu, SMD,[a] Wan-lin Zhang, DDS,[a] Zu-yan Zhang, DDS, PhD,[b] Yun-tang Wu, DDS,[b] and Xu-chen Ma, DDS, PhD,[c] Beijing, China
PEKING UNIVERSITY SCHOOL AND HOSPITAL OF STOMATOLOGY

Objective. The aim of this study was to investigate with cone-beam computed tomography (CBCT) the locations of impacted maxillary canines and resorption of neighboring incisors.
Study design. Two hundred ten impacted maxillary canines were analyzed using CBCT images. The locations of the impacted canines were assessed and angular and linear measurements were taken using NewTom proprietary software. In addition, root resorption of neighboring incisors was investigated.
Results. Among these impactions, 45.2% were impacted buccal-labially, 40.5% were impacted palatally, and 14.3% in the midalveolus. The locations varied: mesial-labial impaction (n = 67), mesial-palatal impaction (n = 74), in situ impaction (n = 31), distal impaction (n = 12), horizontal impaction (n = 18), and inverted impaction (n = 8). Quantitive measurements further depicted these variations. Root resorption was present in 27.2% of lateral and 23.4% of central incisors, and 94.3% of these resorptions occurred where the impacted canines were in close contact with the incisors.
Conclusion. The location of impacted maxillary canines varies greatly in 3 planes, and the resorption of neighboring permanent incisors is common. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:91-8)**

Impaction is defined as a failure of tooth eruption at its appropriate site in the dental arch, within its normal period of growth.[1] Impacted maxillary canines are the most frequently impacted teeth after the third molars, with a prevalence ranging from approximately 1% to 3%.[1-4] Maxillary canines are important aesthetically and functionally, but impacted canines are more difficult and time consuming to treat. Moreover, impacted canines vary greatly in the inclination and location and can lead to resorption of neighboring incisors, as well as cystic degeneration.[5,6] The orthodontic-surgical management of impacted canines requires an accurate diagnosis and localization of the impacted canine.[2] Historically, several radiographic techniques have been recommended, including periapical, occlusal, panoramic, and cephalometric radiographs, or a combination of these approaches.[3] When using these techniques, however, the appearance of the longitudinal axis and the relationship with the neighboring bony and dental structures are often inaccurate because these complex structures overlap in the maxillofacial region. In such cases, therefore, several authors have used computed tomography (CT)—particularly spiral CT—for localization of the impactions and for evaluation of resorption of incisors, due to the excellent tissue contrast and precise three-dimensional images afforded by this technique.[1,5] However, the relatively high radiation dose and high cost have restricted its use in the evaluation of tooth impaction.[2,7,8] In recent years, a series of cone-beam computed tomography (CBCT) units have been devel-

[a]Associate Professor, Department of Oral Radiology, Peking University School and Hospital of Stomatology.
[b]Professor, Department of Oral Radiology, Peking University School and Hospital of Stomatology.
[c]Professor and Chairman, Department of Oral Radiology and Center for Temporomandibular Disorders, Peking University School of Stomatology, Beijing, China.
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oped and used for localization of tooth impaction; these machines use cone-shaped radiation to gather information in the maxillofacial region, with high spatial resolution and significantly decreased radiation doses.[2,7-10] Despite this, a comprehensive analysis of the three-dimensional locations and orientations of impacted canines is lacking.[1,2,4,7] The purpose of this study was to evaluate and quantify the variations of location and inclination of impacted maxillary canines and to determine the root resorption of related incisors by a retrospective analysis of CBCT images in 175 subjects.

MATERIAL AND METHODS

The study sample comprised 175 patients with impacted or ectopically erupting maxillary canines. These patients were referred for localization of these impacted teeth between July 2002 and August 2005, using cone-beam CT (NewTom Model QR-DVT 9000, Verona, Italy). The CBCT images were collected from the workstation of the CT unit. Two hundred ten impacted canines were retrospectively studied. Patients with combined incisor and canine impactions were not included in this study. The mechanical structure, imaging capture, and reconstruction processes have been described in earlier studies.[2,7,11] Briefly, the plane for primary reconstruction is aligned parallel to the occlusal plane. The reconstruction volume ranges within 40 to 50 axials for inspection of the relationship between the impacted canines and peripheral bony and dental structures. Imaging data were analyzed with the software provided by the manufacturer (NewTom 9000 Version 3, 10). The following records were evaluated in the CT workstation for every subject: (1) the three-dimensional variations of impaction—in each case, the vertical inclination was considered first, followed by the mesiodistal migration and buccolingual crown location; (2) linear and angular measurements of the inclination and location of the impacted canines to the maxilla structures—these measurements were made on axial and transaxial views and were based upon the methods used by Walker et al.[2]; (3) follicle size measured at the widest area from the crown to the periphery of the follicle— only the distances larger than 3 mm were recorded; and (4) contact of impacted canine to the incisors and resorption of the incisors—resorption of the incisors was assessed by axial and transaxial views and was graded in 1 of the following 4 categories (based on the grading system suggested by Ericson and Kurol[5]):

- no resorption: intact root surfaces
- mild resorption: resorption midway to the pulp or more, the pulp lining being unbroken
- moderate resorption: the pulp is exposed by the resorption, the involved length of the root is less than one third of the entire root
- severe resorption: the pulp is exposed by the resorption, and the involved length is more than one third of the root

The longitudinal axis of the impacted canine was defined with the aid of a three-dimensional distance calibration toolbar in the NewTom software, which automatically connected a line between the cusp tip and the root apex in the axial view after these 2 points were selected by the users. Subsequently, a transaxial view through the long axis was created. On the axial plane, the distances from the cusp tip to the midline of the maxilla were measured perpendicularly, and the angle between the canine and the midline was calculated (Fig. 1, *A*). On the transaxial view through the long axis of the canine, the angle from the canine to occlusal plane was measured (Fig. 1, *B*). The vertical zone of the cusp tip to the dental arch was categorized as coronal, cervical one third of the root, middle one third of the root, apical one third of the root, and supra-apical. In addition, 30 normally erupted canines were randomly selected as a control group, and similar measurements were taken. All the measurements were taken twice by the first author (D.-G. L.) and the mean was used.

Statistical analysis

Statistical analyses were conducted using SPSS software (version 11.0, SPSS Inc., Chicago, IL). A Student *t* test was carried out to compare the differences between the different variations of impaction and the control group (the group including 30 normally erupted canines). For the vertical zone, a chi-square test was conducted to compare the differences between the variations of impaction. The root resorption of incisors was also analyzed by chi-square test to evaluate the association between resorption and canine contact. The level of significance was set at $P < .05$.

To determine the reliability and reproducibility of the occlusal plane, the tracing of the long axis of impacted canines, and the angular and linear measurements, 10 cases with impacted canines were randomly selected, and primary reconstruction of the CBCT images was performed twice—at least 1 day apart—with the plane aligned parallel to the occlusal plane. Each reconstructed set of images was traced twice, at least 1 day apart, for the long axis of impacted canines. Each tracing was measured twice, also at least 1 day apart. Analysis of variance on randomized complete-block design was performed to determine the intrarater reliability for the duplicate measurements.

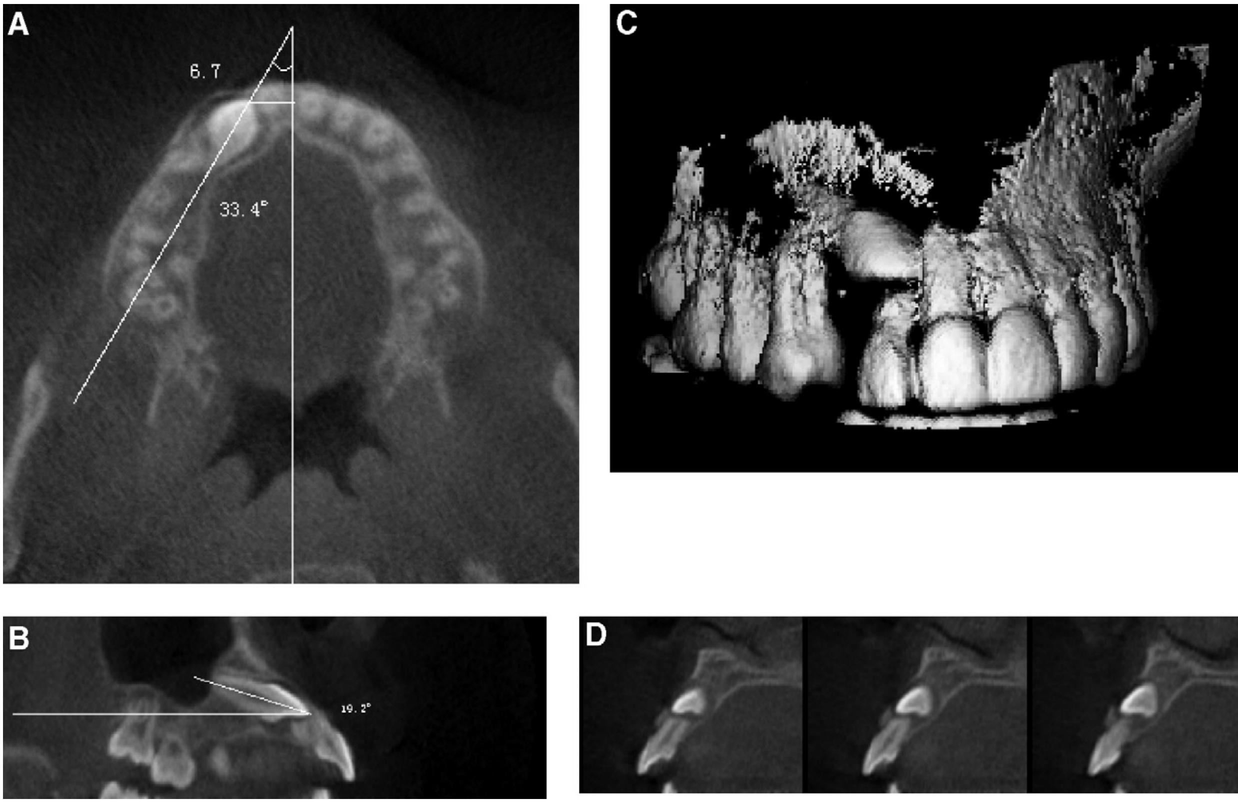

Fig. 1. **A,** Axial view showed an impacted tooth 6 situated distally to tooth 8 and in contact with tooth 8, the horizontal angle of tooth 6 to midline was 33.4° and distance from cusp tip to midline was 6.7 mm. **B,** A transaxial view through the long axis of tooth 6 showed the vertical angle of tooth 6 to the occlusal plane (19.2°). **C,** Three-dimensional view showed the impacted canine situated mesio-labially to tooth 7. **D,** Sequential transaxial views showed that the cusp tip of tooth 6 located labially to the root apex of tooth 7. Note the severe resorption of the root.

Table I. Distribution of maxillary canines according to sex and age in a sample of 175 patients

		Age		*Impacted canines*		
	Number	*Range*	*Mean ± SD*	*Unilaterally*	*Bilaterally*	*Total*
Male	55	10-59	17.1 ± 7.8	43	12	67
Female	120	10-45	16.7 ± 6.5	97	23	143
Total	175	10-59	16.9 ± 6.9	140	35	210

RESULTS

Characteristics of patients and variations of impacted canines

Of the 175 patients, 55 were male and 120 were female. Ages ranged from 10 to 59 years, with a mean age of 16.9 ± 6.9 and a median of 14 years. One hundred forty patients presented with unilateral impacted canines and 35 with bilateral impactions (Table I). Among the 140 unilateral impacted canines, 87 were on the right and 53 on the left side. Two cases involved supernumerary teeth in the incisor region, and 1 involved odontoma near the impacted canine.

According to the three-dimensional images of CBCT, 184 impacted canines were occlusally orientated. Of them, 67 canines were mesial-labially impacted (Fig. 1), 74 canines were mesial-palatally impacted (Fig. 2), 31 canines were impacted mesio-distally in situ (Fig. 3), and 12 canines were distally impacted to the premolar or molar region (Fig. 4). In addition, 18 impacted canines were nearly horizontally orientated to the occlusal plane (Fig. 5), and 8 impacted canines were apically orientated (Fig. 6). Therefore, the variations of location of the 210 impacted canines were summarized as mesial-labial impaction (M-L-I), mesial-palatal impaction (M-P-I), in situ impaction, distal impaction, horizontal impaction, and inverted impaction.

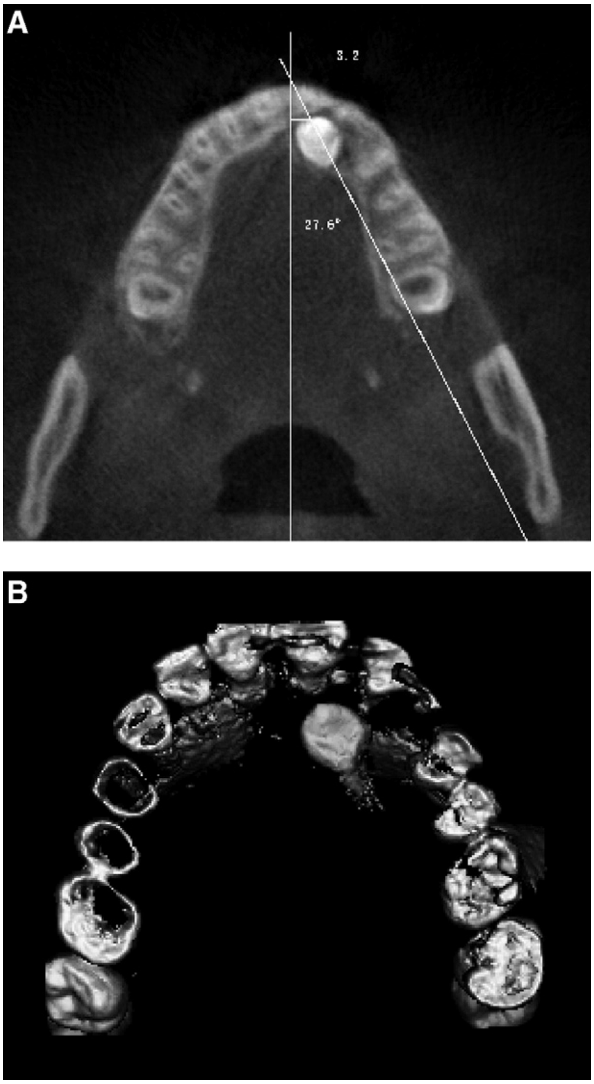

Fig. 2. **A** and **B,** Axial and three-dimensional (bottom view) views showing tooth 11 situated palatally to tooth 9 and tooth 10.

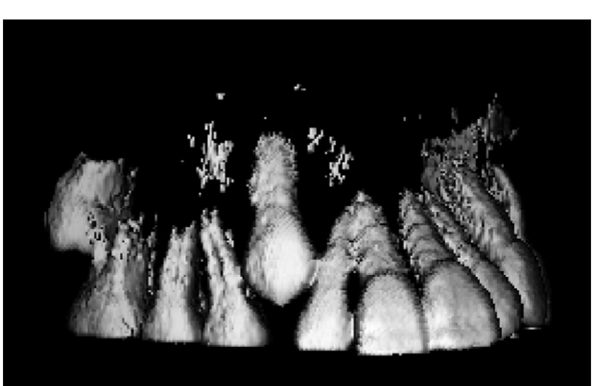

Fig. 3. Three-dimensional view shows tooth 6 located mesiodistally in situ.

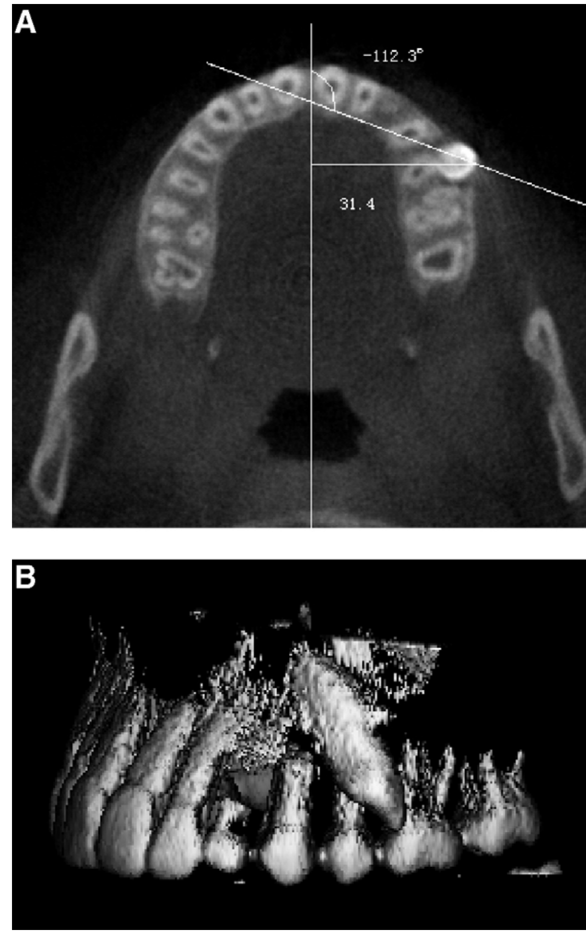

Fig. 4. **A,** The cusp tip of tooth 11 was located at the buccal aspect of tooth 13. Note the horizontal angle of the canine to midline (−112.3°) and the distance from cusp tip of the canine to midline (31.4 mm). **B,** Three-dimensional view clearly shows the spatial relationship of the distal-buccal-projected canine to the dental arch.

As far as the anterior-posterior crown location was concerned, 75 canines were located in the central incisor region, 67 were in the lateral incisor region, 14 were between the central and lateral incisors, 17 in the premolar region, 2 high in the anterior wall of maxillary sinus, and 35 were mesiodistally correct in situ.

In addition, buccolingual crown locations were distributed as 95 canines (45.2%) impacted buccally or labially, 85 canines (40.5%) impacted palatally, and 30 canines (14.3%) in the central alveolus.

Three-dimensional locations of the 210 canines calculated by angles and distances

Analysis of variance test showed high intrarater reliability for the duplicate measurements. The coefficient of interclass correlation (*R* value) was 0.998 for

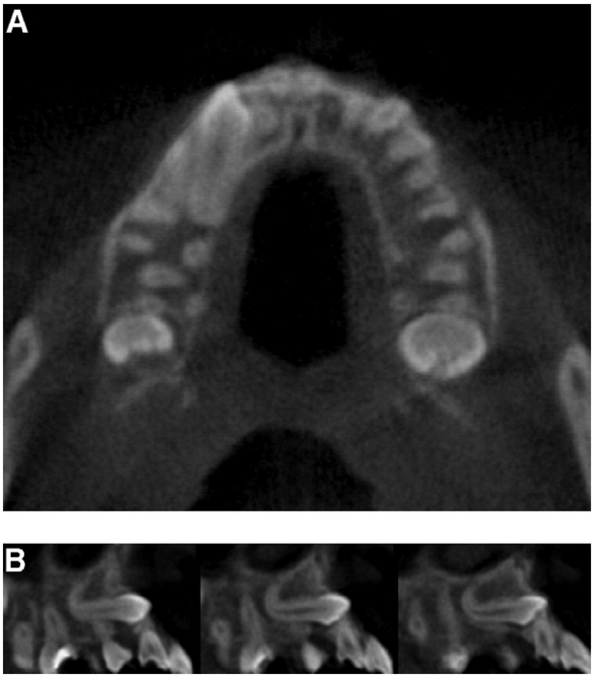

Fig. 5. Axial (**A**) and (**B**) transaxial views showed a horizontally orientated tooth 6. Note the curvature of the apical one third of the canine.

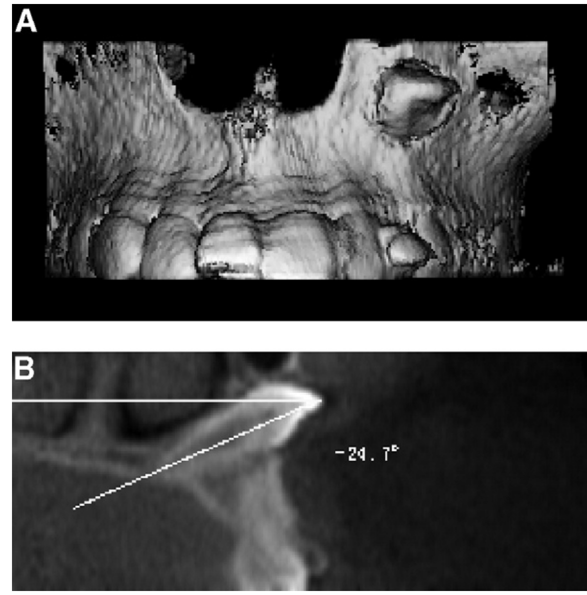

Fig. 6. **A,** Three-dimensional view showing an inverted tooth 11 located high at the anterior wall of the maxillary sinus. **B,** Transaxial view showed the inverted canine at the supra-apical region of tooth 12. Note the vertical angle of the long axis of the canine to the occlusal plane (−24.7°).

the horizontal angle measurements, 0.993 for the linear measurements, and 0.999 for the vertical angle measurements.

Measurements showed that the horizontal angle of the impacted maxillary canines varied from −199.9° to 101.4°, and vertical inclination of the long axis varied from −75° to 77.8°. The horizontal distance and vertical zone also varied to a large extent. The horizontal angles of M-L-I and M-P-I were larger than those in the control group, and distances were smaller than those in the control group, indicating that the crowns of these impactions were projected mesially, with the cusp tip located closer to the midline than normal canines. In distal impactions, the horizontal angle was significantly lower than in the control group. Horizontal impactions were significantly different from the control group in the vertical angle, as well as in the horizontal angle, consistent with the characteristics of their horizontal orientation and mesial projection. The vertical angle of inverted impactions was significantly lower than in the control group (Table II).

The distribution of the vertical zone of the 210 impacted canines is presented in Table III. A Pearson chi-square test revealed a significant difference between M-L-I and M-P-I (χ^2 = 12.2; P = .016). The vertical zones of the former were mainly in the apical one third and middle one third, whereas the vertical zones of the latter were mainly in the middle one third and cervical one third.

The contact relationship between the incisors and impacted canines and distribution of root resorption

Fifty-six of the 206 lateral incisors (4 aplasia) were resorbed, resulting in a resorption rate of 27.2% (Table IV). Fifty-three of the 161 laterals with canine contact were resorbed, whereas only 3 of 45 laterals without canine contact were resorbed. The correlation between contact and resorption was highly significant (χ^2 = 12.3; P <.001). Forty-nine of the 209 central incisors (1 missing) were resorbed, giving a resorption rate of 23.4%. Forty-six of the 78 centrals with canine contact were resorbed, whereas only 3 of the 131 centrals without canine contact were resorbed, again showing a high correlation between contact and resorption (χ^2 = 87.5; P < .001). In total, the resorptions were mild in 49 cases, moderate in 33 cases, and severe (Fig. 1, *D*) in 23 cases. On the other hand, root resorption occurred only on the lateral incisors in 36 impacted canines, only on the central incisors in 29 impacted canines, and on both in 20 impacted canines. Therefore, resorption was associated with 85 (40.5%) of the 210 impacted canines. With regard to the mesial migration of the crown, 65 incisor resorptions were discovered in 75 impacted canines mesially located in the central

Table II. Statistics of angular and linear measurements for 210 impacted canines

Impaction	*No. of cases*	*Horizontal angles (mean ± SD)*	*Horizontal distances (mean ± SD)*	*Vertical angles (mean ± SD)*
M-L-I	67	24.6 ± 18.9***	6.5 ± 4.0***	30.5 ± 12.4***
M-P-I	74	54.7 ± 15.4***	3.8 ± 2.4***	43.5 ± 13.1***
In situ impaction	31	10.3 ± 32.3***	13.6 ± 3.6***	58.4 ± 13.3*
Distal impaction	12	−96.6 ± 62.3**	22.2 ± 7.9	42.6 ± 17.1**
Horizontal impaction	18	22.0 ± 30.7***	8.4 ± 6.1***	4.8 ± 5.7***
Inverted impaction	8	−25.9 ± 35.1	16.6 ± 4.7	−44.7 ± 22.9***
Control	30	−24.1 ± 9.5	18.4 ± 1.6	64.8 ± 5.0

M-L-I, mesiolabial impaction; *M-P-I,* mesial-palatal impaction.
*$P < .05$.
**$P < .01$.
***$P < .001$.

Table III. Distribution of the vertical zone of the cusp tips of 210 impacted canines

Impaction	*Supra-apical*	*Apical 1/3*	*Middle 1/3*	*Cervcal 1/3*	*Coronal*
M-L-I	4	27	18	14	4
M-P-I	1	11	37	23	2
In situ impaction	0	2	11	18	
Distal impaction	1	6	1	3	1
Horizontal impaction	6	10	2		
Inverted impaction	8				
Total	20	56	69	58	7

M-L-I, mesiolabial impaction; *M-P-I,* mesial-palatal impaction.

Table IV. Contact relationship between incisors and impacted canines and distribution of resorption in the central and lateral incisors

	Lateral incisor (4 missing)		*Central incisor (1 missing)*		
Type of resorption	*No touch*	*Touch*	*No touch*	*Touch*	*Total*
No	42	108	128	32	310
Mild	1	31	0	17	49
Moderate	1	12	3	17	33
Severe	1	10	0	12	23
Total	45	161	131	78	415

incisor region (86.7%), whereas only 34 incisors (42.0%) were resorbed in the 81 impacted canines located at the lateral incisors or between the central and lateral incisors ($\chi^2 = 87.5$; $P < .001$). The other 6 incisor resorptions occurred in the 35 impacted canines located mesial-distally in situ.

Among the 210 impacted canines, only 27 canine follicles were larger than 3 mm. The mean size was 4.6 ± 1.0 mm, with a range from 3.2 to 6.7 mm.

DISCUSSION

The prevalence of maxillary canine impaction appears to vary within a range of 0.9% to 3.0%, depending on the population examined. Females are reported to be more commonly affected.[2-4,12,13] In European subjects, canines are impacted palatally at least 2 to 3 times more frequently than labially.[4] In Asian subjects, however, the impacted canines were usually midalveolus or labial, and the prevalence ratio of European: Asian for a palatal position has been reported to be be 5:1 (Peck et al.[14]). In our study, the buccolingual positions of impacted canines were 45.2% labial, 40.5% palatal, and 14.3% midalveolus, consistent with the findings of Peck et al.

The etiology of impacted canine remains unclear. Adjacent peg-shaped or missing lateral incisors have been suggested to contribute to the palatally impacted canines by not providing proper guidance to the canine during its eruption.[12,13] However, Peck et al.[14] have stated that the etiology of palatally impacted canines is genetic in origin. The etiology of labially impacted canines is due to an inadequate arch space.[12-14]

Angular and linear measurements indicate that maxillary canine impaction varies greatly, and there is no common mode of impaction. The commonly used descriptions in the literature, namely buccal, palatal, and midalveolus, are apparently too simple to provide a comprehensive picture for these complex impactions. In this study, we summarize these impactions into 6 variations, with an aim of convenient description of the complex locations of impacted canines. The former 4 variations depicted a mesiodistal displacement of the occlusally orientated impactions in the dental arch. In addition, horizontal and inverted impactions reflected the vertical orientation abnormality of the impactions to the dental arch; M-L-I and M-P-I were the most common, representing 67.1% of the study sample, and were commonly mentioned in the literature.[13] Nevertheless, distal, horizontal, and inverted impactions were scarcely mentioned in the literature. The angular and linear measurements further depicted the spatial variations of the impacted canines in 3 planes. These variations, as well as these measurements, 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. Though the occlusal plane and reference lines were created according to the author's experiences, the reliability or reproducibility of them was good according to the statistical analysis.

Incisor resorption in this study was present in 27.2% of lateral incisors and 23.4% of central incisors. The percentage of lateral resorption was comparable with previous reports from Ericson and Kurol[5] (38%) in a CT study of 156 ectopically impacted maxillary canines, but was lower than the reported percentage of 66.7% by Walker et al.[2] By contrast, the percentage of central resorption was higher than reported by Ericson and Kurol[5] and Walker et al.[2,5] The possible reasons for these differences may be related to sampling differences, differences in subject age range, and expertise in reading the CT images. Therefore, resorption of incisor is a common phenomenon and should be anticipated in all patients with impacted canines.[5,13] In addition, the size of follicles were within a range of 3.2 to 6.7 mm in 27 impacted canines, indicative of a propensity for cystic degeneration. Hence, we recommend routine use of CBCT for the localization of impacted canines, particularly for those with severely displaced canines, and for those with suspected incisor resorption or cystic degeneration.

The mechanism of root resorption following maleruption and the factors involved in the process are not clear. Most authors have stressed the role of physical pressure due to the migration of the maxillary canine.[5] This theory is supported by the findings from the present study. In this study, 53 of 56 resorbed lateral incisors and 46 of 49 resorbed central incisors were in close contact with the impacted canines, indicating that incisor resorption was significantly correlated with contact between the incisor and impacted canine. The mesial position of the canines also influences the rate of incisor resorption, in that a more medial canine position was associated with a higher resorption rate. This finding was consistent with previous studies.[5,6]

The proper treatment of impacted maxillary canines depends on patient age and cosurgical procedure, general oral health, type of impaction, presence of spacing and crowding, and associated complications such as resorption of adjacent teeth and cystic degeneration.[12,15] Treatment alternatives include interceptive treatment, surgical exposure and orthodontic alignment, autotransplantation, or even extraction of the impacted canine.[15-18] For patients 10 to 13 years of age, and under conditions where adequate space exists, Ericson and Kurol[13] recommend the extraction of the deciduous canine as the treatment of choice to correct palatally impacted canines. Some patients may not wish to consider any form of treatment if the deciduous canine is retained, and there are no other significant malocclusions.[13,15] Horizontal and inverted impactions represent a severe vertically abnormal path of eruption, therefore extraction of the canine is in most cases desirable, or otherwise the canines may be left in situ, provided that they are far away from the normal dentition.[13,15,17] Mesial-labial impaction and M-P-I can be treated with surgical exposure and orthodontic alignment, if an interceptive treatment seems inappropriate.[18] Distal impactions may be dealt with by using methods similar to those used with M-L-I and M-P-I, though the direction of traction is different. 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.

In conclusion, the position of impacted maxillary canines varied greatly, both in the vertical and horizontal inclination and in the vertical and horizontal position. Of them, 45.2% were impacted buccal-labially, 40.5% were impacted palatally, and 14.3% were in the central alveolus. With the aid of CBCT images, impactions were summarized as 6 variations. Among them, M-L-I and M-P-I are mesially displaced and account for 67.1% of the study sample. In situ impactions are mesial-distally central in the canine region. Distal, horizontal, and inverted impactions are rare and are scarcely mentioned in the literature. Incisor resorption is present in 27.2% of lateral and 23.4% of central incisors, and most of the resorptions occurred where the canine was in close contact with the incisors.

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Reprint requests:

Deng-gao Liu, SMD
Associate Professor
Department of Oral Radiology
Peking University School and Hospital of Stomatology
Beijing 100081, China
kqldg@bjmu.edu.cn