Diagnosis and localization of the maxillary impacted canines by using dental multi-slice computed tomography 3D view and reconstructed panoramic 2D view

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ABSTRACT

Background: Diagnosis and treatment planning can be difficult with conventional radiographic methods as the orthodontic-surgical management of impacted canines requires accurate diagnosis and precise localization of the impacted canine and the surrounding structures. This study was aimed to localize and evaluate weather there is any differences in the diagnostic information provided by multi-slice computed tomography three dimensional volumetric CT images and two dimensional reconstructed panorama images (derived from CT) in subjects with impacted maxillary canines.

Materials and Methods: Thirty patients including 24 female and 6 male with mean age of 18 years with suspected unilaterally or bilaterally impacted maxillary canines were evaluated on images taken with Brilliance™ 64, Philips multi-detector computed tomography. The spatial relationships of the impacted maxillary canines relative to the adjacent structures was evaluated using linear and angular measurements, and the adjacent lateral incisor root resorption was assessed with three dimensional and two dimensional visualization software.

Results: The inclination of the impacted maxillary canine measured to the midline and to the occlusal plane did not differ significantly when it was evaluated using the two imaging modalities. However, there were significant differences between the 3D and 2D images with respect to the impacted maxillary canine vertical height, bucco-palatal localization, and in detecting the proximity and root resorption of the adjacent lateral incisors.

Conclusion: Dental CT volumetric images provide more reliable and accurate information for diagnosing the maxillary impacted canine position, inclination, distance from adjacent structures, and detection of lateral incisors rootresorption.

Keyword: Impacted maxillary canines, computerized tomography, root resorption. **(J Bagh Coll Dentistry 2014; 26(1):159-165).**

INTRODUCTION

Maxillary canines contribute significantly to the esthetic and chewing functions, any disturbances in the eruption of permanent maxillary canines can cause problems in the dental arch and adjacent teeth, which require special care and attention.Therefore, orthodontists should diagnose canine ectopic eruption early, trying to prevent retention of these teeth [(1)].

The term “localization” means: “determination of the site or place of any process or lesion” [(2)]. The identification of an impacted canine is only the first step in the proper diagnosis of such a case, after examining complicating factors such as pathologic findings and possible root resorption of the adjacent teeth, the orthodontist’s focus quickly turns to the localization of the impacted tooth, the correct diagnosis depends on clinic, radiographic and/or tomographic exams. Besides, visualization of the correct location and orientation is essential for determining the proper course of treatment, which may consist of observation, extraction, or attempted alignment of the impacted tooth in conjunction with limited or comprehensive orthodontics [(3)].

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The conventional two-dimensional (2D) radiographic imaging was the most common modality used clinically as the primary diagnostic radiograph for the localization of impacted canines, treatment planning, and evaluation of the treatment result. Panoramic radiography is a standard diagnostic tool in orthodontics for the preoperative diagnosis of routine cases. However, the diagnostic accuracy and validity for localizing impacted canines and adjacent structures can be underestimated due to deficiencies, such as distortion projection errors, blurred images, and complex maxillofacial structures that are projected onto a 2D plane, thus increasing the risk of misinterpretation [(4,5)].

Correct treatment planning requires accurate diagnosis and localization of the impacted canine in relation to the adjacent structures, assessing root resorption and the changes in root surface morphology, which normally requires three-dimensional (3D) information, and the 3D CT overcomes the limitations of conventional radiography and found to be superior to the conventional 2D radiographs for the localization of impacted canines and in the assessment of incisor root resorption [(6,7)]. Also, it is outstanding for assessing the positions of the teeth and their mutual relationship compared to other diagnostic methods which gives a good basis for clinical considerations when complications occur during eruption

[8], so several authors have therefore suggested that the use of computed tomography (CT) in such cases was more beneficial [9-11]. The purpose of this study was toinvestigatethe location of the maxillary impacted canines; the contact; overlapping; and resorption severity of the neighboring incisors, and to Compare and evaluate whether there is any differences in the diagnostic information provided by multi-slice computed tomography three dimensional CT images and two dimensional reconstructed panorama images in patients with impacted maxillarycanines.

MATERIALS AND METHODS

The Sample

Dental CT images were collected from 30 patients (24 females, 6 males) who were referred for localization of either unilateral or bilateralmaxillary impacted canines. A total of 36 maxillary impacted canines were studied, including 6 bilateral impactions, 17 left unilateralimpactions, and 7 right unilateral impactions. Thepatients' ages ranged from 16 to 20 years, with a mean age of 18 years, and were collected from Al Karkh General Hospital/the Computerized Tomography department between January 2013 till June 2013.

The following criteria were used in the selection of the total sample, according to the information taken from the clinical and radiographical examination of the patients:

1. They have full set of permanent dentition in both jaws "excluding the 3rd molar" , with unilaterally or bilaterally maxillary impacted canines.
2. Patients should have no large metal restorations including crowns and fillings.
3. Patients with no history of orthodontic treatment or orthognathic surgery.
4. No history of dento-facial deformities, pathologic lesions in the jaws or facial trauma.
5. No gross distortion of the dental arches due to acleft lip/palate.
6. Good medical history, no hormonal disturbance.

Method

For each patient in the sample a clinical examination and computerized tomographic imaging had been done using multidetector computed tomography (Philips, Brilliance 64,Netherlands**)**, then the CT images were collected from the workstation and the imaging data were reconstructed, analyzed, and stored in the CT acquisition workstation. The parameters included a tube voltage of 80 KV, a tube current of 30 mA, anda scanning time of 2.5 seconds.Two different sets of images had been obtained for each patient, the first set consisted of 3D volumetric CT images and the second set consisted of 2D reconstructed panoramic images generated by the CT.Software from the manufacturerallows for secondaryreconstructions to be produced that show manyviewpoints of the structures of interest. These secondaryreconstructions include transaxial, panoramic, and3D views. Measurements were made on these views (distances and angles).This study focused on the following:

1- Type of impaction: The permanent maxillary canine location in relation to the adjacent teeth buccally, palatally, or in the line of the arch (mid-alveolus).

2- Width of the permanent maxillary canine crown (for both impacted one and normally erupted one), and both maxillary central incisors crown were measured in millimetersfrom the mesial contour of the crown to the distal contour on a line perpendicular to their long axis [12,13].

3- Linear measurements for accurate localization of the impacted canines to the maxilla structures, these measurements were based upon the methods described by Walker *et al.* [14], in which two linear measurement were estimated: (a) Canine horizontal distance to the midline; (b) Canine vertical distance to the occlusal plane, both of them were measured in millimeters with the Philips software on these views.

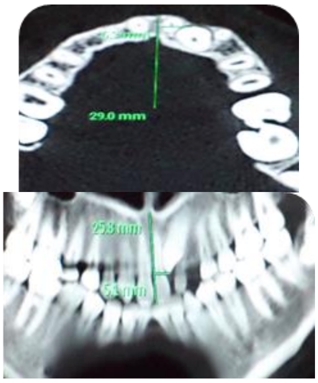

Figure 1: Measurement of the canine horizontal distance to the midline

4- Degree of vertical eruption was estimated in both 3D and 2D views and the vertical zone of the impacted canine to the dental arch was categorized according to Alqerban *et al.* [13] as coronal (cervical) one third of the root, middle one third of the root, apical one third of the root, and supra-apical zone.5- Permanent maxillary canine angulations. Two angles were measured of the inclination and for theaccurate localization of an impacted canine: (a) Canine angulation tothe midline, which was formedby a line bisecting the midline of the jaws and a line through the canine cusp and the apex bisecting the long axis of the impacted canine and was graded according to Walker et al.[14] and Fleming*et al*. in 2009[15]**:** Grade I: 0-15º. Grade II: 16º -30º. Grade III: >= 30º.(b) Canine Angulation to the occlusal plane: The angles measured were formed by a line through the canine cusp and the apex bisecting the long axis of the impacted canine and the occlusal plane based upon methods described by Walker et al.[15].

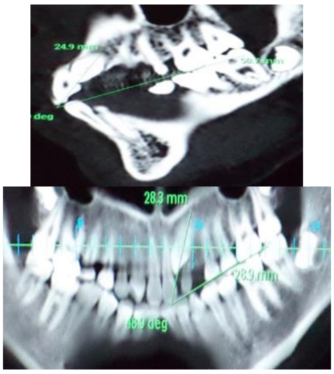

Figure 2: Canine angulation to the occlusal plane.

6- Proximity of the impacted canine to the lateral incisors was examined by both 3D images (coronal, sagittal and axial views) and on 2D panorama image. This was measured as the shortest distance between the impacted canine and the incisor. Contact was defined as proximity of less than 1 mm [16].

7- Canine overlap of the adjacent lateral incisor root: The mesiodistal position of the canine crown tip was assessed and graded upon the methods described by Stivaros and Mandall [17] as following: Grade I: No horizontal overlap.- Grade II: Less than half the root width. - Grade III: More than half, but less than the whole root width. - Grade IV: Complete overlap of root width or more.

8- Severity of root resorption: The resorption defect of the adjacent lateral incisor was assessed by coronal, sagittal and axial 3D views and by 2D panorama view, and was rated based on the grading systems suggested by Ericson *et al*. [16]:

- No resorption: intact root surfaces.
- Mild resorption: resorption extending up to half of the dentine thickness to the pulp.
- Moderate resorption: resorption midway to the pulp or more with the pulp lining being intact.
- -Severe resorption: the pulp is exposed by the resorption.

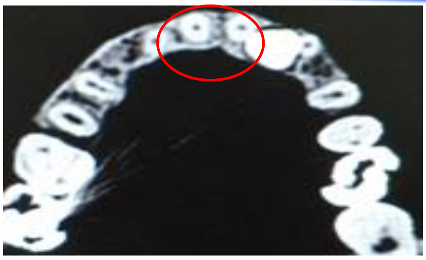

Figure 3: Assessment of the incisor root resorption

For assessment of location, reference lines werecreated that consisted of a horizontal occlusal plane line, and a vertical line bisecting the midline of the jaws. Alldistances were measured perpendicularly from the referencelines to the cusp tip of the tooth, and the angles measured were the angles formed by the line bisectingthe long axis of the tooth and the reference line.

The bucco-palatal localization of the impacted maxillary canine in the 2D panorama by using the ratio of the widest mesio-distal dimension of the impacted canine to the widest mesiodistal dimension of the ipsilateral central incisor which was defined as Canine Incisor Index (CII) and were used in the cases of bilateral canine impaction, while in the cases of the unilateral canine impaction, the impacted canine location was determined by using the Canine Canine Index (CCI) which is defined as the ratio of the widest mesio-distal dimension of the impacted canine to the widest mesiodistal dimension of the normally erupted other side canine, the ratio of the widest mesiodistal dimension of the erupted canine to the widest mesiodistal dimension of the ipsilateral central incisor was defined as control canine incisor Index (C-CII), when the mesio-distal width of the crown of an unerupted canine (as it appeared and measured directly on the reconstructed panorama) was 1.15 times larger (i.e. 15% greater) than that of the adjacent central incisor or contralateral canine then the canine was palatally displaced**,** otherwise it was considered to be labially located[19, 20].

Statistical analysis

All the data of the sample was subjected to computerized statistical analysis using SPSS version 17 for windows XP. The statistical analysis included:

1- <u>Descriptive statistics:</u> (Mean, standard deviation, standard error, percentage, percentage of agreement, statistical tables).
2- <u>Inferential statistics:</u> (Independent sample t-test, Wilcoxon signed ranks test, Chi-square test, the likelihood ratio, paired samples t-test: For intra and inter-examiner calibration).

P (Probability value) level of more than 0.05 was regarded as statistically non-significant.While a P-level of 0.05 or less was accepted as significant.

RESULTS

Characteristic of patients

A total of 36 impacted maxillary canines were studied in 30 patients, which includes 6 males (20%) and 24 females (80%); aged 16 to 20 (mean, 18) years. Twenty four patients (80%) presented with unilateral impacted canines and 6 (20%) with bilateral impactions. Among the 24 unilateral impacted canines, 7 (23.3%) were on the right and 17 (56.7%) were on the left side.

Impacted maxillary canine and central incisor mesiodistal width

The mean value of the impacted maxillary canines mesiodistal width in the 3D CT (8.01± 0.59) was higher than its' value in the 2D panorama (7.76 ± 0.69), with a significant difference between them. Also, t-test was done to detect any differences in the mean values of the ipsilateral central incisor mesiodistal width between the 3D CT group and the direct clinical measurement, and there was no significant difference between them (p>0.05). While regarding the 2D panorama a highly significant difference was found between the direct clinical measurements and the 2D panorama in the ipsilateral central incisor mesiodistal width measurement (P≤ 0.001).

3D CT and 2D panorama localization of canines by distances

<u>Impacted canine horizontal distance</u>

The statistical analysis showed that the horizontal distance of the impacted canine to the midline varied to a large extent in both the 3D CT group and the 2D panorama; in the 3D CT the mean value was (10.33 ± 5.15mm), while the 2D panorama showed a higher SD (7.01) and the mean value was (10.24 mm).Wilcoxon signed ranks test showed no significant difference between them as (P>0.05).

<u>The Maxillary Impacted Canine Vertical Position</u>

The descriptive analysis showed that the mean value of the impacted canines vertical height in the 3D CT were (10.12 ± 3.58mm), while the highest SD (5.53) were found in the 2D panorama with a mean value (11.83 mm). The Wilcoxon signed ranks test revealed a significant difference between the 3D CT and 2D panorama (P≤0.05), as it was significantly higher in the 2D panorama group. Yet, the vertical zones distribution of the impacted maxillary canines showed that the highest percentage of the canine impaction in both the 3D CT and the 2D panorama group was found in the apical zone followed by the middle zone, then by the cervical zone and the least percentage was found in the supra-apical zone with no significant difference (P>0.05) between both imaging modalities and the percentage of agreement was 47.22%.

3DCT and 2D panorama localization of canines by angles

<u>The impacted maxillary canines angulation to the midline</u>

In general the majority of the impacted maxillary canines in both the 3D CT and 2D panorama were found in sector III and II respectively(in which the canine angulation was more than 16^{o}), with statistically no significant difference between them.

The impacted maxillary canines angulation to the occlusal plane

When comparing the impacted maxillary canines angulation to the occlusal plane, it showed a higher mean value and S.D in the 3D CT (54.42˚± 20.09) than in the 2D panorama (49.88˚ ± 16.96).However, the wilcoxon signed ranks test revealed no significant differencebetween them.

The impacted maxillary canine bucco-palatal position

Regarding the bucco-palatal impacted canine localization, the descriptive statistics demonstrates that in the 3D CT most of the impacted maxillary canines were found on the palatal and mid-alveolus side(41.7 %), and the least percentage were found on the buccal side(16.7%), while in the 2D panorama most of the impacted canines were found on the buccal side(63.9%), the least percentage were found on the palatal side(19.4%) and about 16.7% couldn't be accurately localized.The chi-square analysis showed a highly significant difference (P ≤ 0.001) between the 3D CT and 2D panorama group and the percentage of agreement was 19.44%. Moreover,there was significant correlation in the 3D CT between the impacted canine bucco-palatal and vertical position; as most of the buccally and mid-alveolus impacted canines were found in the cervical and apical zone, while most of the palatally located canines were found in the middle and apical zone respectively.

The relationship between the impacted maxillary canines and the ipsilateral incisors

<u>The overlap relationship between the impacted maxillary canines and the ipsilateral incisors</u>

Regarding the canine overlap relationship with the adjacent incisors in the 3D CT about 50% of the impacted canines lack the horizontal overlap with the adjacent incisors, while the reminder canines were ranging between overlap grade II and III respectively, and non of them reached to grade IV overlap; unlike the 2D panorama group canine horizontal overlap evaluation in which the highest percentage of the impacted canines scored grade IV overlap. The chi-square revealed a highly significant difference between both imaging modality and the percentage of agreement was 33.33% between them.

The contact relationship between the impacted maxillary canines and the ipsilateral incisors

In general the contact relationship were the same for both the 3D CT and 2D panorama; in which most of the impacted maxillary canines were contacting the adjacent lateral incisors, with no significant differences between them.

Root resorption of the adjacent lateral incisors.

The statistical analysis as seen in the table (6) showed that the percentage of the lateral incisor root resorption within the 3D CT was nearly equally distributed between the no resorption and mild resorption grade, however the majority of the lateral incisors adjacent to the impacted canines in the 2D panorama showed no resorption grade. Also, the inferential statistics demonstrated a highly significant difference in the detection of the presence or absence of root resorption of the adjacent lateral incisor between the 3D CT and 2D panorama as (**$P \leq 0.001$**).Furthermore the statistical analysis showed highly significant correlation ($P \leq 0.001$) between the incisor contact and it's resorption in the CT group.

DISCUSSION

Regarding the central incisor mesiodistal width measurement, there was no significant difference between the direct clinical measurement on the patient mouth and on 3D CT, which confirm that the 3D CT imaging allows greater accuracy and reliability for linear measurements which improved visualization of the anatomical situation of the impacted maxillary canines, these results are consistent with Abdel-Salam *et al.* [18] who stated that by CT the distances and angles in relation to adjacent structures could be measured in millimeters and degrees with very high accuracy. Yet, thesignificant difference that were found in the central incisor mesiodistal width betweenthedirect clinical measurement and the 2D panorama measurement, and in the impacted maxillary canine mesiodistal width between the 3D CT and the 2D panoramaclarify the analysis limitations of the 2D panoramadue to the geometric distortion, superimposition of structures, rotational errors and linear projective transformation.

Linear and angular measurements are frequently used as comparative parameters for radiological assessment. They were utilized in this study due to their relative use as predictors of canine eruption, The high standard deviations of the horizontal distance which were found for both the 3D CT and 2D panorama indicates that maxillary canine impaction varies greatly, and there is no common mode of impaction these results are consistent with Liu et al. [19].

The difference foundin the mean vertical height between the 3D CT and 2D panorama could be due to the change in the cant of the occlusal plane during the reconstruction of the panorama, besides the inclination of the impacted canine relative to the vertical plane in the upper arch could effect its vertical height,the vertical level of the clinical crown have an influence on the estimated outcome of treatment; the higher the canine position with respect to the occlusal plane, the longer and more difficult the treatment [17].

There was a general observation that the canine–midline angulations tended to be greater than 30˚ (Grade III) in both the 3D and 2D imaging modalities, it is worth mentioning that the canine angulation to the midline and the occlusal plane influences the treatment decision as a more horizontally positioned canine is considered more difficult to orthodontically align [17].

In the current study the palatally and midalveouls impacted maxillary canine were more common than the buccal impactions which could be attributedto less referral of buccally impacted canines as they are usually palpable. Also, this investigation showed a significant correlation in the 3D CT examination between the maxillary impacted canine bucco-palatal position and its' vertical positionin which most of the buccally and the mid-alveolus impacted canines (50%) were found in the cervical zone of the adjacent lateral incisor, crowding here could be implicated as the main cause of buccal displacement of the maxillary canines. The remaining 50% of the buccally impacted canines were found in the apical zone which agrees with other previous studies [19-21].This might be due to that these canines have developed from ectopically located and buccally directed tooth buds, which places them in the genetic control area.Regarding the palatally impacted canines the majority of them were found in the middle zone which supports the same result of Chaushu *et al.* [21] and Liu *et al.* [19]. This could be explained by the possibility that environmental factors may give rise to palatal displacement of canines generated by genetic anomaly of the adjacent teeth [20].

It is usually considered that the prognosis for orthodontically aligning an impacted permanent canine is worse if the crown overlaps more than half the adjacent incisor root [17]. In the present study the 3D CT examination revealed that most of the impacted maxillary canines were found in sector I and II which contradict the overlapping estimation result in the 2D panorama as a larger overlap was observedand most of the impacted canines were found in sector IV, due to the horizontal deformations that affects the reconstructed panorama, resulting in the decreased dispersion of objects in the horizontal plane.

The number of the diagnosed resorbed roots of the adjacent laterals in the 3D CT was three times more than that diagnosed by the 2D panorama, which agrees with many previous studies [6,14,19]. This significant difference is due to the ability of the 3D CT to overcomes the problems with conventional radiography and substantially increases the perceptibility of detecting root resorption by eliminating the overlap, distortion and increasing the image resolution, which has great significance in patient management as the diagnosis of the impacted canine accompanied by resorption of lateral incisor roots requires immediate separation of both teeth in order to stop resorption progression [13].

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 rather than mediation of resorption by swelling of the dental follicle [11, 14, 19], this theory is supported by the findings from the present study, in which the impacted canine was in contact (shortest distance less than 0.5 mm) with the lateral incisor in all of the resorption cases, indicating that incisor resorption was significantly correlated with contact between the impacted canine and the adjacent incisor. The mesial position of the canines may also influences the rate of incisor resorption, as it was observed that a more medial canine position was associated with a higher resorption rate.

Presently, the three dimensional dental CT is the most accurate method available to orthodontist for diagnosing the maxillary impacted canine position, inclination, distance from adjacent structures, impaction complications, and detection of lateral incisors root resorption which has a significant impact on diagnostic and therapeutic interventions.

REFERENCES

1- Park J, Srisurapol T, Tai K. Impacted Maxillary Canines: Diagnosis and Management. Dental CE today J 2012; 62-6.
2- Novak PD Dorland's illustrated medical dictionary. 27th ed. Philadelphia: Saunders; 2004.
3- Bishara SE. Impacted maxillary canines: a review. Am J Orthod Dentofac Orthop 1992; 101(2):159-71.
4- Elefteriadis J N, Athanasiou A E. Evaluation of impacted canines by means of computerized tomography. Int J Adult Orthod Orthognath Surg 1996; 11: 257–64.
5- Stewart JA, Heo G, Glover KE, Williamson PC, Lam EW, Major PW. Factors that relate to treatment duration for patients with palatally impacted maxillary canines. Am J Orthod Dentofac Orthop 2001; 119: 216–25.
6- Ericson S, Kurol PJ. Resorption of incisors after ectopic eruption of maxillary canines: a CT study. Angle Orthod 2000; 70(6):415-23.
7- Heimisdottir K, Bosshardt D, Ruf S. Can the severity of root resorption be accurately judged by means of radiographs? A case report with histology. Am J Orthod Dentofac Orthop 2005; 128:106-9.
8- Preda L, La Fianza A, Di Maggio EM, Dore R, Schifno MR, Campani R, et al. The use of spiral computed tomography in the localization of impacted maxillary canines. J Dentomaxillofac Radiol 1997; 26: 236-41.
9- Peene P, Lamoral Y, Plas H. Resorption of the lateral maxillary incisor: assessment by CT. J Comput Assist Tomogr 1990; 14:427–9.
10- Schmuth GP, Freisfeld M, Köster O, Schüller H. The applicationofcomputerizedtomography (CT) in cases of impacted maxillary canines. Eur J Orthod 1992; 14(4): 296-301.
11- Ericson S, Bjerklin K, Falahat B. Does the canine dental follicle cause resorption of permanent incisor roots? A computed tomographic study of erupting maxillary canines. Angle Orthod 2002; 72: 95–104. (IVSL).
12- Nagpal A, Keerthilatha M, Setty S, Sharma G. Localization of impacted maxillary canines using panoramic radiography. J Oral Sci 2009; 51(1): 37-45.
13- Alqerban A, Jacobs R, Fieuws S, Willems G. Comparison of two cone beam computed tomographic system versus panoramic imaging for localization of imparted maxillary canines and detection of root resorption. Eur J Orthod 2011; 33: 93-102. (IVSL).
14- Walker L, Reyes Enciso, James M. Three-dimensional localization of maxillary canines with cone-beam computed tomography. Am J Orthod Dentofac Orthop 2005; 128: 418-23.
15- Fleming PS, Scott P, Heidari N, Dibiase AT. Influence of radiographic position of ectopic canines on the duration of orthodontic treatment. Angle Orthod 2009; 79(3): 442-6. (IVSL).
16- Ericson S, Bjerklin K, Falahat B. Does the canine dental follicle cause resorption of permanent incisor roots? A computed tomographic study of erupting maxillary canines. Angle Orthod 2002; 72: 95–104.
17- Stivaros N, Mandall NA. Radiographic factors affecting the management of impacted upper permanent canines. J Orthod 2000; 27: 169-173.
18- Abel-Salam E, El-Badrawy A, Tawfik A. Multidetector dental CT in evaluation of impacted maxillary canine. Egypt J Radiol Nuclear 2012; 43: 527–34.
19- Liu D, Zhang W, Zhang Z, Wu Y, Ma X. Localization of impacted maxillary canines and observation of adjacent incisor resorption with cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 105(1): 91-8.
20- Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. Angle Orthod 1994; 64: 249–56.
21- Chaushu S, Chaushu G, Becker A. The use of panoramic radiographs to localize displaced maxillary canines. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999; 88(4): 511-6.

Table 1: Impacted maxillary canine and central incisor mesiodistal width.

Variables		Descriptive statistics			Inferential statistic	
		Mean	S.D.	S.E.	t-test	p-value
MD 3	3D CT	8.01	0.59	0.10	2.23	0.033 *
	2D panorama	7.76	0.69	0.12		
MD 1	Direct clinical	8.41	0.76	0.13	-0.9	0.373 (NS)
	3D CT	8.42	0.77	0.13		
MD 1	Direct clinical	8.41	0.77	0.13	4.44	0.000 ***
	2D panorama	7.43	1.33	0.22		

Table 2: Impacted canine horizontal distance

Image type	Descriptive statistics				Comparison	
	Median	Mean	S.D.	S.E.	Wilcoxon Signed Ranks Test	p-value
3D CT	10.15	10.33	5.15	0.86	-1.25	0.212 (NS)
2D panorama	8.35	10.24	7.01	1.17		

Table 3: The mean of the vertical height of the impacted maxillary canines

Image type	Descriptive statistics				Comparison	
	Median	Mean	S.D.	S.E.	Wilcoxon Signed Ranks Test	p-value
3D CT	9.95	10.12	3.58	0.60	-2.47	0.014 *
2D panorama	10.95	11.83	5.53	0.92		

Table 4: Bucco-palatal impacted canine position

Position	Descriptive Analysis				% of agreement	Comparison	
	3D CT		2D Panorama			Likelihood ratio (d.f.=3)	p-value
	No.	Percentage	No.	Percentage			
Buccal	6	16.7%	23	63.9%	19.44%	42.72	0.000 ***
Palatal	15	41.7%	7	19.4%			
Mid-alveolus	15	41.7%	0	0%			
Can not be determined	0	0%	6	16.7%			

Table 5: Impacted canine angulation with the midline

Position	Descriptive statistics				% of agreement	Comparison	
	3D CT		2D Panorama			X^2 (d.f.=3)	p-value
	No.	Percentage	No.	Percentage			
Supra apical	3	8.3%	2	5.6%	47.22%	0.403	0.94 (NS)
Apical	12	33.3%	14	38.9%			
Middle	11	30.6%	10	27.8%			
Cervical	10	27.8%	10	27.8%			

Table 6: Incisor root resorption

Resorption Grade	Descriptive analysis				% of agreement	Comparison	
	3D CT		2D Panorama			Likelihood ratio (d.f.=3)	p-value
	No.	Percentage	No.	Percentage			
No resorption	18	50.0%	33	91.7 %	47.22%	29.77	0.000 ***
Mild	17	47.2 %	0	0 %			
Moderate	1	2.8 %	2	5.6 %			
Severe	0	0 %	1	2.8 %			