Original Study

RELIABILITY OF IMPACTED MAXILLARY CANINE FEATURE MEASUREMENT OBTAINED BY CBCT

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ABSTRACT

Aim: The aim of this study was to evaluate the reliability of impacted maxillary canine feature measurements taken by cone beam computed tomography (CBCT).

Materials & Method: Two examiners assessed CBCT radiographs of 102 impacted maxillary canines to determine inter-examiner reliability, and re-examined 20 randomly selected cases among them to report intra-examiner reliability. CBCTs with a 9" or 12" field of view and Dolphin™ 3D (version 11.5) were used. Angulation, vertical position, rotation, and the angle between the canine and lateral incisor were measured as quantitative variables. Dilacerations, overlap of canines with incisors or midline, resorption of lateral incisors, and the positions of the canines were measured qualitatively. SPSS version 20 and Med Calc were used to analyze the data. The reliability of the quantitative variables was reported by the intraclass correlation coefficient (ICC) and Bland–Altman plots. Wilcoxon and kappa were used for the qualitative analyses.

Results: The inter-examiner reliability assessment of the quantitative measurements resulted in ICC values of 0.74–0.99 (ICC = 0.74 for rotation and ICC = 0.99 for angulation of canine relative to lateral incisor). The intra-examiner reliability assessment of the quantitative measurements resulted in ICC values of 0.93–0.99 (ICC = 0.93 and ICC = 0.99 for the same variables).The Bland–Altman plot confirmed the ICC analysis results. The lowest coefficient of agreement (kappa) was 0.67 for dilaceration and the highest was 1.00 for the position of the impacted canine.

Conclusion: Angulation of the canine had the highest reliability, while rotation and dilaceration had the lowest reliability.

Key words: Canine, Tooth Impaction, Cone Beam Computed Tomography.

Introduction

Impaction is defined as a failure of tooth eruption at its appropriate site and time in the dental arch.[1] The maxillary canine is the second most commonly impacted tooth, after the third molars, with a reported incidence of 0.8%–2.8%, depending on the population examined.[2-5] These teeth require orthodontic-surgical management; therefore, an accurate diagnosis and localization of these teeth is necessary.[6,7] A surgeon exposes the displaced tooth safely and efficiently by knowing the exact position of the displaced tooth and its position to adjacent anatomical structures. On the other hand, an orthodontist will accurately determine the direction in which the traction has to be made to avoid contact with roots of neighboring teeth.[8] Several radiographic techniques have historically been recommended to localize impacted canines, including periapical, occlusal, panoramic, and cephalometric radiographs or a combination of these approaches;[9] however, image enlargement, distortion, structure overlap, and poor positioning are limitations of these techniques.[10] In modern practice, the localization of impacted maxillary canines and the assessment of lateral root resorption have been drastically improved using information obtained from three-dimensional (3D) investigations. The computed tomography (CT) systems used in some studies[11-13] are expensive and expose patients to high doses of radiation.[14] With the introduction of low dose volumetric CT systems, cone beam computed tomography (CBCT) has allowed clinicians to take advantage of the 3D information provided at a low radiation dose and with relatively low cost.[15] The aim of this study was to investigate the inter-examiner and intra-examiner reliability of CBCT measurements to localize impacted maxillary canines.

Materials and Method

CBCT radiographs of 102 impacted canines from 80 patients were collected from three private clinics and one university department. All patients were >14 years old. CBCT radiographs (CBCT machine: New Tom 3G Volume scanner; QR SRL, Verona, Italy) of good quality that showed the maxilla and maxillary dentition (field of view of 9 or 12) were included in this study, while CBCT radiographs displaying incomplete formation of canine roots and those with an incomplete view of the maxilla and maxillary teeth were excluded.

Dolphin™ 3D (version 11.5) was used for the measurements. Each patient's name was replaced by a special code; this code was entered into the software with the patient's demographic data. DICOM files were imported into the Dolphin imaging software. A 3D virtual image was created from the original file and was carefully oriented according to the maxillary occlusal plane. The midsagittal plane was oriented vertically using the axial, coronal, and sagittal views. Measurements were taken on the computer screen in multiplaner and 3D views.

We measured angulation of the canine relative to the occlusal plane, vertical positioning of the canine cusp tip relative to the occlusal plane, and rotation of the impacted canine relative to a line of occlusion on CBCT images to localize impacted teeth in the sagittal, vertical and transverse dimensions. The angles between the impacted canines and lateral incisors were measured in orthopantomographs (OPG) constructed from CBCT.

Dilaceration, or overlap of the canines with incisors or the midline, resorption of lateral incisors, and the type of impacted canine (buccal or palatal) were measured qualitatively. These measurements and their classification were selected according to a study by Al-ansari[16] in which the location of the maxillary impacted canine was compared in 3D and two-dimensional (2D) views.

Two post-graduate students were trained and calibrated to examine impacted canine localization using images not included in this study. The calibration protocol included an explanation of the 3D measurement tools in the Dolphin imaging software and a demonstration of the measurements to be made for this study. Five images were used for training and calibration. Each examiner was considered calibrated when the intraclass correlation coefficient (ICC) for quantitative variables between two time measurements and between their measurements and those from the trainer was > 0.9.

Definitions of the variables measured

Angulation of impacted canine: The angle between the long axis of the impacted canine and the occlusal plane (line that connects the premolar cusp tip to the incisal edge of the central teeth) was measured in the sagittal view. [Figure 1A]

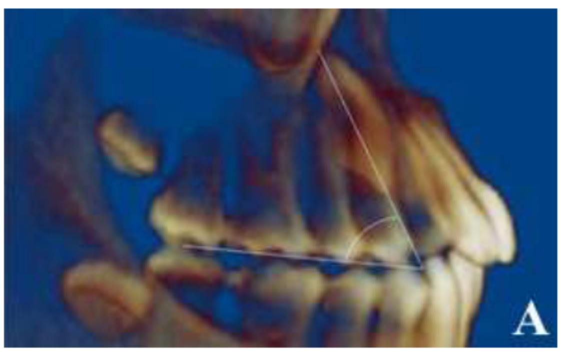

Figure 1a: *Measurement of angulation of the canine relative to the occlusal plane.*

Vertical position of the impacted canine: Distance in millimeters from the impacted canine cusp tip to the occlusal plane (line connecting the premolar cusp tip to the incisal edge of central teeth) was measured in the sagittal view. [Figure 1B]

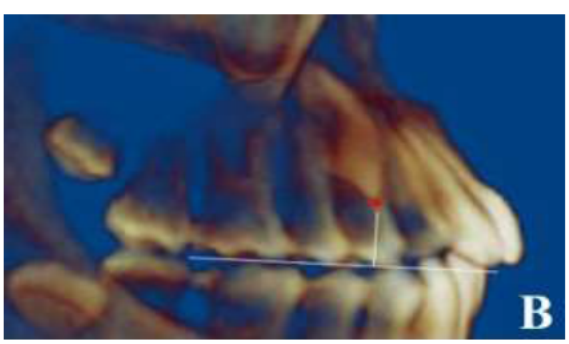

Figure 1b: *Measurement of the distance from the canine cusp tip to the occlusal plane.*

Rotation of impacted canine: Maximum convexity in the mesial and distal surfaces of the canine crown was determined in 3D views with two landmark points using the axial and sagittal views. The third point was located along the occlusal plane in the dental arch on the 3D images in the occlusal view. The angle that connected these three points was the degree of canine rotation. [Figure 1C]

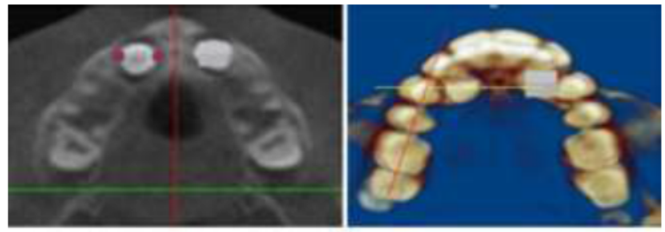

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Figure 1c: *Measurement of the degree of canine rotation.*

Angle of canine relative to lateral incisor: An OPG was constructed from the CBCT for this measurement. The angle between two lines that passed through the long axis of the canine and lateral incisor was measured.

Root dilaceration of impacted canine: Each tooth was categorized into one of four groups according to dilaceration.

- Group 1: No dilaceration.
- Group 2: Dilaceration of 45–90° in the 2 mm apex.
- Group 3: Dilaceration of 45–90° in more than a 2 mm apex. Group 4: Dilaceration ≥ 90° in any part of the root. A 3D view of the maxilla was used to detect dilacerations.

Overlap of impacted canine: The state was divided into five groups according to the position of the canine's cusp tip to characterize and classify overlap of the impacted canine with the incisor and the midline.

- Group 1: Distal of the lateral incisor,
- Group 2: Mesial of the lateral incisor,
- Group 3: Distal of the central incisor,
- Group 4: Mesial of the central incisor, and
- Group 5: Cross the midline. The frontal view was used for this classification. [Figure 1D]

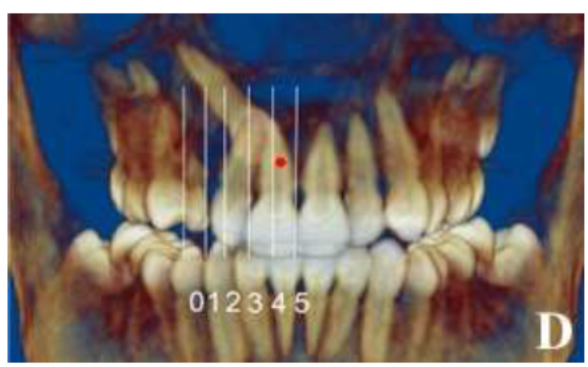

Figure 1d: *Classification of canine overlap.*

Root resorption of lateral incisors: Axial and sagittal views were used to detect root resorption. Root resorption was categorized into three groups:

- Group 1: No resorption,
- Group 2: Resorption up to half the way from the root surface to the pulp chamber, and
- Group 3: Exposure of the pulp chamber.

The two examiners measured these parameters in 102 cases, and the measurements were used to calculate inter-examiner reliability. To evaluate intra-examiner reliability, 20 cases were selected randomly, and each examiner measured the parameters once again in these 20 cases 1 month after the first measurements. The data were checked carefully, and extreme outliers were examined. SPSS version 20 (SPSS Inc., Chicago, IL, USA) and Med Calc (Med Calc, Ostend, Belgium) were used to analyze the data. The variables were classified into two categories to report inter- and intra-examiner reliability. Vertical distance, angulation, rotation, and the angle between the canines and lateral incisors were considered quantitative variables, whereas resorption, dilacerations, and overlap were considered qualitative variables. ICC with 95% confidence intervals, Bland–Altman (17) plots, and the paired *t*-test were used to report inter- and intra-examiner reliability of the quantitative variables. The Wilcoxon test and kappa were used to report reliability of the qualitative variables. The reliability was ranked according to Tables 1 and 2 (18,19).

Value of ICC	Strength of Reliability
Above 0.9	Excellent
0.75 – 0.9	Good
0.5 – 0.75	Moderate
Below 0.5	Poor

Table 1: Ranking of intraclass correlation coefficient (ICC) values

Value of ICC	Strength of Reliability
Above 0.9	Excellent
0.75 – 0.9	Good
0.5 – 0.75	Moderate
Below 0.5	Poor

Table 2: Ranking of Kappa values

Results

The ICC and paired *t*-test were used to report inter- and intra-examiner reliability of the quantitative variables. The results are shown in Table 3 for inter-examiner reliability and in Table 4 for intra-examiner reliability. Table 3 indicates that all variables except rotation had excellent inter-examiner reliability (ICC > 0.9). Canine rotation had moderate inter-examiner reliability (ICC = 0.74). Table 4 shows that all variables had excellent intra-examiner reliability (ICC > 0.9).

Variables	Examiner A (Mean ± SD)	Examiner B (Mean ± SD)	ICC Value	95% CI		p value
				Lower Bound	Upper Bound	
Vertical distance	11.37 ± 4.05	11.40 ± 3.93	0.931	0.900	0.953	0.848
Angulation	50.63 ± 15.17	50.04 ± 15.53	0.965	0.949	0.976	0.148
Rotation	45.25 ± 27.89	43.14 ± 25.51	0.740	0.890	0.948	0.055
Angle 2 to 3	49.65 ± 20.46	49.54 ± 20.30	0.992	0.996	0.998	0.739

Table 3: Descriptive statistics and the inter-examiner reliability for the quantitative measurements

Variables	Examiner A1 (Mean ± SD)	Examiner A2 (Mean ± SD)	ICC	95% CI		p value
				Lower Bound	Upper Bound	
Vertical distance	11.13 ± 3.82	10.99 ± 4.05	0.955	0.891	0.982	0.588
Angulation	53.72 ± 11.70	53.32 ± 12.44	0.989	0.971	0.346	0.346
Rotation	44.15 ± 22.66	41.79 ± 20.92	0.931	0.833	0.211	0.211
Angle 2 to 3	51.95 ± 23.82	51.37 ± 23.48	0.999	0.996	0.999	0.057
Variables	Examiner B1 (Mean ± SD)	Examiner B2 (Mean ± SD)	ICC	95% CI		p value
				Lower Bound	Upper Bound	
Vertical distance	11.06 ± 4.23	10.98 ± 4.22	0.976	0.941	0..991	0.695
Angulation	51.49 ± 14.50	51.01 ± 13.89	0.977	0.977	0.996	0.278
Rotation	39.49 ± 22.88	40.78 ± 21.16	0.906	0.779	0.962	0.511
Angle 2 to 3	51.68 ± 23.17	51.62 ± 23.71	0.999	0.996	0.999	0.833

Table 4: Descriptive statistics and intra-examiner reliability for the quantitative measurements

Bland–Altman plots were also used to check the ICC results. The plots confirmed the ICC analysis. According to these plots, all variables had acceptable inter- and intra-examiner reliability (plots with narrow limits) except for the degree of rotation of the impacted canine. The plots for degree of rotation with wide and unacceptable limits are shown in Figures 2–4.

The inter-examiner agreement results of the Wilcoxon and Kappa tests of reliability for the qualitative variable are shown in Table 5 and those for intra-examiner agreement are shown in Table 6.

Variables		Examiner A	Examiner B	Kappa	Wilcoxon
Buccal-palatal	Buccal	12	12	1.000	1.000
	Palatal	74	74		
	Mid	16	16		
Resorption	No resorption	71	66	0.706	0.346
	Less than half	18	24		
	More than half	8	7		
	Exposure	5	5		
Dilaceration	No dilaceration	87	88	0.768	0.739
	Less than 2 mm	10	8		
	More than 2 mm	5	5		
	Sharp angle	0	1		
Overlap	Distal of lateral	26	25	0.881	0.142
	Mesial of lateral	11	10		
	Distal of central	36	33		
	Mesial of central	25	31		
	Cross the midline	4	3		

Table 5: Descriptive statistics and the inter-examiner reliability for the qualitative measurements

Variables		Examiner A		Kappa	Wilcoxon	Examiner B		Kappa	Wilcoxon
Buccal-palatal	Buccal	0	0	1.000	1.000	0	0	1.000	1.000
	Palatal	20	20			20	20		
	Mid	0	0			0	0		
Resorption	No resorption	12	13	0.730	0.414	11	13	0.731	0.102
	Less than half	4	4			6	5		
	More than half	2	1			2	2		
	Exposure	2	2			1	0		
Dilaceration	No dilaceration	17	18	0.780	0.317	17	16	0.672	0.157
	Less than 2 mm	1	1			2	3		
	More than 2 mm	2	1			1	1		
	Sharp angle	0	0			0	0		
Overlap	Distal of lateral	3	3	1.000	1.000	3	3	0.858	0.180
	Mesial of lateral	5	3			2	2		
	Distal of central	6	6			6	5		
	Mesial of central	7	7			8	9		
	Cross the midline	1	1			1	1		

Table 6: Descriptive statistics and intra-examiner reliability for the qualitative measurements

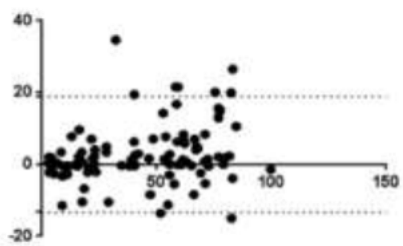

Figure 2: Bland–Altman plot; inter-examiner reliability of the degree of rotation, Horizontal axis: Means of examiner's A and B measurements for the degree of rotation. Vertical axis: Difference in measurements by examiner's A and B for the degree of rotation of an impacted canine.

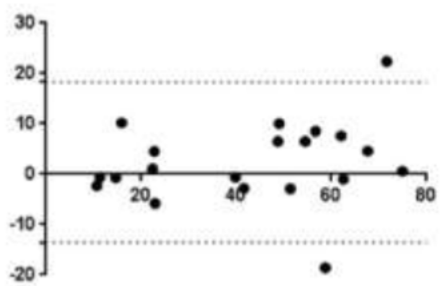

Figure 3: Bland–Altman plot; intra-examiner reliability for the degree of rotation (examiner A). Horizontal axis: Means of degree of rotation measurements. Vertical axis: Difference in the degree of rotation measurements.

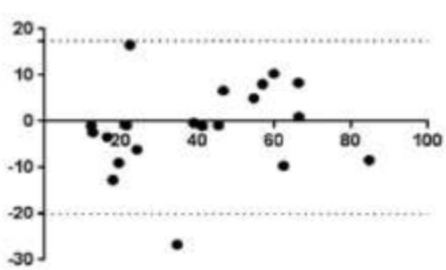

Figure 4: Bland–Altman plot; intra-examiner reliability of the degree of rotation (examiner B). Horizontal axis: Means of the degree of rotation measurements. Vertical axis: Difference in the degree of rotation measurements.

Discussion

Our findings indicate that measuring angulation of the canine relative to the occlusal plane, the vertical position of the canine relative to the occlusal plane, and the angulation of the canine relative to the lateral incisors on an OPG constructed from CBCT had excellent inter- and intra-examiner reliability. The degree of canine rotation had moderate inter-examiner reliability (ICC = 0.74). Intra-examiner reliability for canine rotation was excellent (ICC > 0.9). Identifying the type of impacted canine (buccal or palatal) and overlap of the canine relative to the incisors or the midline had very good inter- and intra-examiner agreement (Kappa > 0.8), whereas dilacerations of the canine root and resorption of lateral incisors had good inter- and intra-examiner agreement (Kappa 0.6–0.8).

An OPG reconstructed from the CBCT images in this study was used to determine the reliability of angulation of the canine relative to the lateral incisor. Most clinicians are more acquainted with this traditional view, and angulation of the canine relative to the lateral incisor has been measured in many studies.[20-22] On the other hand, no single standard 3D view has been defined for measuring the angulation between the canine and lateral incisor. In this way, determining the reliability of the measurements on the panoramic view among other 3D measurements has significant merit for comparison.

Different radiographs have been used to properly localize impacted canines. Ericson and Kurol reported that plain radiography alone was insufficient for detecting impacted teeth.[11] Rajath et al. compared three methods to localize impacted canines. They showed that a periapical radiograph, CT axial, and 3D images revealed 100% agreement for the surgical exposure results, whereas OPG showed 50%–80% agreement for surgical exposure.[23] In our study, measurements on OPG had the highest reliability relative to the other 3D measurements.

Al-Ansari measured angulation of the canine relative to the midline and occlusal planes, the vertical position of the canine relative to the occlusal plane, the minimum distance between the canine and adjacent lateral incisors, overlap of canines, and lateral root resorption on 3D and 2D views. Their results showed no differences between the two views for the horizontal measurements, while 2D view values were significantly greater than the 3D values for the vertical position of the canine.[16]

Some studies have reported the accuracies of panoramic radiographs, conventional CT, and digital radiography. However, few reports have investigated the accuracy of CBCT, particularly intra- and inter-examiner reliability.[24] Nagpal et al. assessed the reliability of some linear measurements used to localize impacted maxillary canines on panoramic radiographs. All P- values in their study were > 0.05, indicating acceptable inter- and intra-examiner reliability for these measurements.[25]

Al-mutased localized impacted canines on 3D views. They located the canine cusp tip and root apex in angular and linear measurements in three planes (mid sagittal, occlusal, and frontal). The inter-examiner reliability analysis showed that the difference in the linear measurements between the two examiners was 0.02 mm and the difference was 1° for the angular measurements.[26]

Intra-examiner and inter-examiner reliability of impacted canine measurements was evaluated by Dalessandin et al. in 2013. Intra-examiner agreement in their study for one of the raters was 0.49 and that for the other was 0.41, indicating moderate intra-examiner agreement. Inter-examiner agreement was 0.94, indicating strong agreement.[27] This result was in contrast to our study that all linear and angular measurements had higher intra-examiner reliability than inter-examiner reliability. This can be explained based on the examiner's interpretation of the landmark definition and individual differences in anatomy. Furthermore, operator experience using CBCT images and software may have influenced the results and had a greater impact on inter-examiner reliability.[28]

The orthodontic treatment methodology for impacted canines depends on various factors, such as the location of the impacted canine in the dental arch relative to adjacent incisors, the distance from the occlusal plane, overlap of canine crowns, and canine angulations. These variables are also used as predictors for the duration of orthodontic treatment until alignment of the canine is achieved.[29] In the present study, the reliability of these variables was high (ICC > 0.9 and Kappa > 0.8). Therefore, we measured these variables with acceptable reliability on CBCT images to localize impacted canines.

The choice of treatment is influenced by factors, such as rotation, root resorption, and dilacerations of the canine,[30] but the reliability of these variables in our study was not as good as in other studies. One of the reasons for this lower reliability for rotation may be the difficulty identifying landmarks in the crown of impacted canines in the 3D view. Use of a classification system for measuring resorption and dilacerations may be a reason for the lower reliability of these two variables. Our results suggest that measuring these variables should be done cautiously on CBCT.

Conclusion

- Angulation of a canine relative to the lateral incisors on an OPG, the vertical position of the canine relative to the occlusal plan, and angulation of the canine relative to the occlusal plane had excellent reliability on CBCT images.
- Rotation of the canine had moderate reliability on CBCT images.
- The type of impacted canine (buccal or palatal) and overlap of canines relative to incisors and the midline had very good reliability on CBCT images.
- Resorption of lateral incisors and dilaceration had good reliability on CBCT images.

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