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A new guide using CBCT to identify the severity of maxillary canine impaction and predict the best method of intervention

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Abstract:

OBJECTIVE: This study aimed to test the intra and inter-rater reliability, reproducibility, and validity of a new guide called the "Cone Beam Computed Tomography-Maxillary Canine Impaction (CBCT-MCI)," designed to assess the position, severity, and predictability of the maxillary canine impaction (MCI) treatment intervention using Cone Beam Computed Tomography (CBCT).

MATERIALS AND METHODS: This study is a retrospective radiographic review of 44 patients with unilateral or bilateral MCI. A total of 56 maxillary impacted canines' CBCT radiographs were analyzed using the new CBCT-MCI guide, with each of its 10 items scored. The total scores of the 10 items were then compared to a scale to predict the best treatment intervention of MCI: normal spontaneous eruption, surgical-orthodontic traction, or surgical extraction. Radiologists and orthodontists have developed, tested, and retested the CBCT-MCI guide on the same 56 maxillary impacted canines using CBCT radiographs to check its reliability and reproducibility using the Kappa coefficient. Furthermore, the validity of this guide was tested by comparing the predicted best treatment intervention with the actual treatment administered to the assessed impacted maxillary canine using the Kappa coefficient and percentage of agreement using cross-tabulation.

RESULTS: The result of this study showed significantly strong Kappa values of intra-rater agreement (k = 0.91, ($P < 0.0001$) and inter-rater agreement (k = 0.84, $P < 0.0001$). Furthermore, testing the relationship between the two MCI treatment interventions using cross-tabulation, the agreement percentages between the predicated and actual treatment plans of the assessed MCI ranged between 70% and 95.5% with a significantly strong Kappa value (k = 0.82, $P < 0.0001$).

CONCLUSIONS: This study suggests that the CBCT-MCI guide is capable of producing accurate, reliable, and reproducible results in assessing and predicting the type of orthodontic treatment intervention of MCI in a simple, quick, and efficient way.

Keywords:

CBCT, cone-beam computed tomography, maxillary canine impaction

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Introduction

The maxillary permanent canines are the most frequently impacted teeth after the third molars. The reported frequency of maxillary canine impaction (MCI) is around 1.0%–2.2% in most populations.[1,2] In Saudi Arabia , the prevalence of MCI is high. Afify and Zawawi[1] found the prevalence to be 3.3% in their study on the dental anomalies of 878 orthopantomograms taken from patients, aged between 12 and 30 years, who went for dental treatment at the Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia between 2002 and 2011. Similarly, Al-Zoubi *et al*.[3] also found a high percentage of 2.5% of MCI in 354 individuals having impacted

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teeth, excluding third molars in 14,000 patients (age range: 14–70 years) attending the College of Dentistry at Taibah University, from January 2011 to February 2015. However, Alhammadi *et al*.[4] found that the prevalence of MCI was 1.9% in patients who attended the outpatient clinic at the College of Dentistry, Jazan University, Saudi Arabia from January 2015 to October 2016, which is within the range of impacted canines in other populations. Alassiry[5] found that the prevalence of MCI was 3.5% in the Najran (Saudi Arabia) population between January 2016 to February 2019.

Three diagnostic procedures can be used to evaluate impacted canines. These methods are inspection, palpation, and radiography. Accurate radiographs are essential for diagnosing the position of the canine and its relation to the adjacent teeth as well as assessing root resorption of the lateral and/or central incisors.[2,6-8] Furthermore, radiographic analysis of impacted canines is necessary to determine the prognosis and the best mode of treatment.[9,10] In the past, several radiographic methods have been used. The most common methods can be divided into intraoral and extraoral techniques. The intraoral techniques include occlusal and periapical projections, while the extraoral techniques include panoramic, posterior-anterior, lateral cephalometric radiographs, and computed tomography (CT). Identifying canine impactions from panoramic radiography is valuable for the overview and prediction of tooth eruption and treatment results.[8,11] However, panoramic radiography has limitations in assessing the labio-palatal position of impacted canines and root resorption of incisors. Moreover, conventional 2D images have several disadvantages, such as distortion, superimposition of structures, errors in projection, imaging artefacts, and variation in magnification.[7,8,10-12]

CT can detect the location of the displaced canine as well as diagnose associated lesions, such as root resorption of adjacent teeth and the amount of bone surrounding each tooth.[10] However, since the cost and radiation doses are high with CT, its clinical use has been limited.[13,14] In the 1990s, a new system, cone beam computed tomography (CBCT), with reduced radiation exposure compared to conventional CT, was presented for studying dental structures.[15] Since CBCT is a new technique, it is important to evaluate its reliability and validity in measuring and localizing the canine positions and also its precision in making an accurate diagnosis and assessment of the treatment effects. Several studies have investigated the measurement accuracy of CBCT. The main conclusion of these studies revealed that CBCT gives highly accurate and valid measurements.[2,11,10,15]

To the best of our knowledge, no study has provided a simple guide for clinicians to follow in assessing MCI position and severity using CBCT and predicting the best method of intervention. This study introduced a new simple guide called the "Cone Beam Computed Tomography Maxillary Canine Impaction (CBCT-MCI)" guide for use in future studies, becoming a useful tool for orthodontists and maxillofacial surgeons who are not familiar with CBCT interpretation. Thus, this study aimed to test the intra and inter-rater reliability and reproducibility using the CBCT-MCI guide to assess the position and identify the severity of MCI, and test its validity in predicting the best intervention by comparing the predicted treatment protocol to the actual treatment that was administered.

Materials and Method

King Abdulaziz University, College of Dentistry Research Ethics Committee has approved this study (Ethical Committee #040/19). A total of 56 MCIs were examined in CBCT radiographs of 44 patients (12 cases had bilateral MCI). These patients were referred to the radiology department from the orthodontic department in the dental college of the King Abdulaziz University as a part of the patients' diagnosis of MCI. Later, these patients were treated for their impacted canines with orthodontic treatment, either by a spontaneous eruption or surgical orthodontic intervention to pull them into the oral cavity (orthodontic traction), or sent for surgical extraction.

All of the 56 impacted maxillary canines included in this study were chosen to have different difficulty levels of impactions and fulfill the following inclusion criteria:

- All MCI analyzed using CBCT
- Absence of any maxillofacial syndrome, cleft lip and palate, trauma, or tumor
- No previous orthodontic treatment or undergoing orthodontic treatment before CBCT analysis
- All MCI were treated subsequently, and the treatment type is documented in the patient's files

Radiographic procedure

The CBCT examination of 56 impacted maxillary canines was performed with a 360-degree rotation and a volume of 60 × 60 mm set at 0.3 mm voxel size, 5 mA current, 120 kV tube voltage, 4 s of scanning time, and a slice thickness interval of 1.20 mm.

The CBCT image views that were chosen for the examination of the 56 MCIs were the frontal projection view, the axial/transversal view, the sagittal view, and the coronal view. Figure 1 displays example of these CBCT image views.

CBCT-MCI guide

An orthodontist and a radiologist (the authors, both with more than 20 years of experience) created the CBCT-MCI guide comprising 10 items assigned to evaluate the

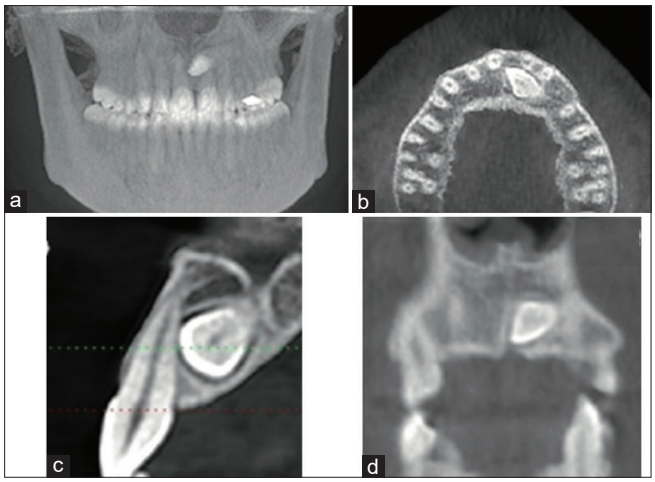

Figure 1: Example of image views obtained from CBCT: (a) frontal view, (b) axial /transversal view, (c) sagittal view, (d) coronal view

position of the MCI and its relation to the surrounding structures in coronal, sagittal, and axial CBCT views. Each item can have one to three subitems describing the severity of the canine condition, and an ascending score is given to each subitem according to its condition. Table 1 shows the CBCT-MCI guide form. All items and subitems of the CBCT-MCI guide describing the position and severity of the MCI were carefully chosen according to the radiographic diagnostic measures documented in the literature.[2,6-8,11-14,16-21] This guide summarizes all CBCT diagnostic methods for examining MCI position and severity conditions. Each of the chosen items was proven to be accurate in the literature.[2,6-8,11-14,16-21] The scores of the 10 items are then added, and the total score is compared to a scale that predicts the best treatment intervention of the assessed MCI as the following:

0 – 5 = Normal spontaneous eruption (NE).

>5 – 9 = Surgical orthodontic traction (SOT).

>9 = Surgical extraction (SE).

An example of how the CBCT-MCI guide was used in assessing MCI is shown in Figure 2 using Item N#2, assessing the position and severity of MCI in CBCT sagittal views.

Results

A total of 44 individuals (56 MCIs) aged 13 – 35 years (mean age of 17 ± 5 years) were included in the study. From the 56 evaluated MCIs, 43% were in males and 57% were in females.

Testing the reliability and the reproducibility of the CBCT-MCI guide

Testing the reliability and reproducibility of the CBCT-MCI guide is done by intra and inter-observer kappa agreement

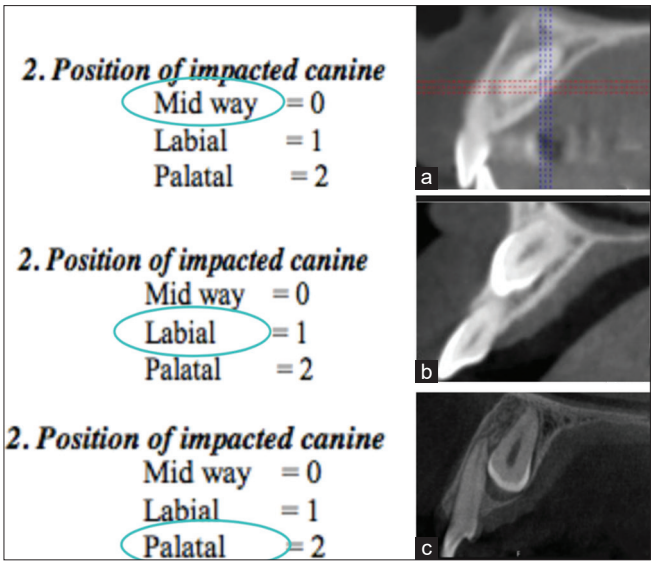

Figure 2: CBCT sagittal views of the maxillary impacted canines in three different positions each with difficulty score. (a) canine in the mid-way, (b) canine labially, (c) canine palatally

statistics [Table 2]. To assess the intra-observer reliability and reproducibility of each measurement technique using the CBCT-MCI guide, the first author (orthodontist) measured the same 56 radiographs twice for each item in the guide at two different times and calculated the intra-observer kappa agreement to be significantly high (k = 0.91 ($P < 0.0001$), indicating the reliability and reproducibility of the results within the same examiner at two separate times. Furthermore, to assess the inter-observer reliability and reproducibility of each measurement technique using the CBCT-MCI guide between the two observers, the two authors (the orthodontist and radiologist) evaluated the same 56 MCI-CBCT radiographs using all the items in the CBCT-MCI guide separately and calculated the inter-observer kappa agreement between them. This showed a high significant value (k = 0.84 ($P < 0.0001$), indicating a reliable and reproducible result between two different examiners.

Table 3 shows the frequency and percentage of the actual treatment intervention of the MCIs that were documented in each patient file and the predicted treatment intervention of the assessed MCIs using the CBCT-MCI guide. The results revealed minor differences in the frequencies and the parentages between the two MCI treatment interventions. In the actual treatment intervention of the 56 maxillary impacted canines, only 8 (14.3%) of the MCIs actually erupted normally with no orthodontic or surgical intervention, which was almost similar to the predicted treatment intervention using the CBCT-MCI guide, which was 10 (17.9%). In addition, 26 (46.4) of the impacted MCIs were actually treated by surgical orthodontic traction, which was almost analogous to the predicated results of 22 (39.3%).

Table 1: The CBCT-MCI guide form

Items Evaluating MCI	Sub-items	Difficulty Degree
N1	Vertical	= 0
Type of impacted permanent canine	Oblique	= 1
	Horizontal	= 2
N2	Mid way	= 0
Position of impacted permanent canine	Labial	= 1
	Palatal	= 2
N3	Retained with resorbed PC roots	= 0
Corresponding of primary canine (PC)	Retained without resorbed PC roots	= 1
	Missed PC	= 2
N4	1/3 root formed	= 0
Stage of permanent canine root formation	1/2 root formed	= 1
	2/3 or Complete	= 4
N5	Away by >2 mm	= 0
Relationship of impacted permanent canine to maxillary sinus	Close by <2 mm	= 1
	In the sinus	= 10
N6	Away by >2 mm	= 0
Relationship of impacted permanent canine to nasal cavity	Close by <2 mm	= 1
	In the nasal cavity	= 10
N7	Normal <2 mm	= 0
Follicular space width of impacted permanent canine	Abnormal >2 mm	= 10
N8	Presence of PDL	= 0
Ankylosis of impacted permanent canine	Absence of PDL	= 10
N9	Away from Lateral or central incisors	= 0
Resorption of central/lateral incisors to impacted permanent canine	Resorbed roots of lateral incisor only	= 2
	Resorbed both lateral and central incisors	= 10
N10		
Associated pathological lesion to	Yes, pathological lesion	= 0
of impacted permanent canine	No, pathological lesion	= 10
Total Score (Sum of 10 items)	0-5=Normal spontaneous eruption of impacted canine=NE	
	>5-9=Surgical orthodontic traction of impacted canine=SOT	
	>9=Surgical extraction of impacted canine=SE	

Table 2: Kappa agreement measurements and its significance level

Measurements	kappa agreement (k)	Significance level (*P*)
Inter-observer kappa agreement	0.91	*P*<0.0001
Intra-observer kappa agreement	0.84	*P*<0.0001
kappa agreement between the two treatment modalities (the predicted and actual treatment interventions)	0.82	*P*<0.0001

Testing the validity of the CBCT-MCG guide

The validity was tested by calculating the degree of agreement between the two treatment modalities (the predicted and actual treatment interventions of the assessed MCIs) using Kappa statistics [Table 2]. It showed a strong significant agreement between the two-treatment plans (k = 0.82, $P < 0.000$).

Table 4 shows a cross-tabulation table to calculate the percentage agreement between the predicted best treatment interventions of MCI according to the CBCT-MCI guide and the actual treatment interventions, which were done to the same impacted canines documented in the patients' treatment files. The percentage agreement was high, ranging between 70% and 95.5%.

Discussion

The second most impacted teeth after the third molars are maxillary canines. In XXXXX, several studies reported higher prevalence percentages of MCI in comparison to other populations.[1-3] CBCT radiographic evaluation is considered the best tool to diagnose impacted canines and it plays an important role in the management of these conditions.[2,6-8,10-14,16-21] However, many clinicians do not know how to interpret CBCT.[2,5-8,11-14,16-20] Therefore, this study introduces a new CBCT-MCI guide to simplify the evaluation of the position and severity of the impacted maxillary canine from all aspects, and assign a difficulty score to predict the best treatment intervention method. Thus, the CBCT-MCI guide could become a useful tool for orthodontists and maxillofacial clinicians if this guide proven to be reliable, reproducible, and valid.

It is vital to test the CBCT-MCI guide's reliability and reproducibility, which means that the diagnostic

Table 3: Frequency and percentage of the actual and predicted treatments of the impacted maxillary canines

Treatment Protocols	Actual Treatment *n* (%)	Predicated Treatment *n* (%)
Normal eruption (NE)	8 (14.3%)	10 (17.9%)
Surgical orthodontic traction (SOT)	26 (46.4%)	22 (39.3%)
Surgical extraction (SE)	22 (39.3%)	24 (42.8%)
TOTAL	56 (100%)	56 (100%)

Table 4: Cross tabulation showing the frequency and percentage of agreement between the actual and predicted treatment interventions of the impacted maxillary canines

Predicated Treatment Intervention	Actual Treatment Intervention			
	NE* (*n*%)	SOT** (*n*%)	SE*** (*n*%)	Total (*n*)
NE* (*n*%)	7 (70%)	3 (30%)	0 (0%)	10
SOT** (*n*%)	1 (4.5%)	21 (95.5%)	0 (0%)	22
SE*** (*n*%)	0 (0%)	2 (8.3%)	22 (91.7%)	24
TOTAL (*n*)	8	26	22	56

Normal Eruption*- Surgical Orthodontic Traction**- Surgical Extraction**

results of this guide in assessing impacted maxillary canine position and severity should be the same when it is assessed by the same operator at different time intervals or when it is assessed by different operators. Many studies like ours used the intra and inter-rater agreement to test the reliability and reproducibility of CBCT measurements.[2,6-8,11] In this study, the results showed a strong significant intra and inter-rater agreement, demonstrating that the CBCT-MCI guide provides reliable and reproducible diagnostic results of MCIs, which is very important for both orthodontists and maxillofacial surgeons, since different diagnostic results of MCIs could lead to very different treatment plans. The items of the CBCT-MCI guide used to assess the position and severity of MCIs using CBCT are documented in the literature to be effective diagnostic examination methods.[2,6-8,10-14,16-21] This guide is summarizing all the documented CBCT diagnostic methods of MCI in ten scored items.

To test the CBCT-MCI guide validity, we compared the predicted treatment interventions of assessed impacted maxillary canines using the CBCT-MCI guide with the actual treatment interventions received and documented in the patient files. To simplify the treatment outcome, the types of treatment interventions were divided into three categories depending on the severity of the impacted maxillary canine; it is either NE, SOT, or SE. These MCI treatment interventions are well documented in the literature.[6-8,10-14,16-21] Results of our study showed a strong significant agreement between the two compared treatment intervention plans, ranging between 70% and 95.5% with kappa agreement of 0.82 index, demonstrating that the CBCT-MCI guide provides a valid prediction of the best treatment intervention protocol. This is very significant in helping both orthodontists and maxillofacial surgeons determine the optimal path of treatment intervention. Choosing the best method of MCI treatment intervention depends on the severity of the CBCT diagnostic examination of the MCI, which is well documented in the literature.[9,10,12,22,23] It is compatible with this study's MCI treatment intervention prediction, stating that as the diagnostic severity of the MCI increases, surgical intervention becomes the preferred alternative. Therefore, the CBCT-MCI guide treatment prediction is made by linking the diagnostic severity score of the assessed MCI with the type of treatment intervention protocol documented in the literature.

Conclusions

The CBCT-MCI guide was proven to be an excellent and simple tool to diagnose the severity of MCI and predict the best method of intervention.

Limitations and recommendations

A limitation of this study was the small sample size. However, because we aimed to develop a prediction model with practical relevance, this study is considered to be of crucial importance in establishing an easily validated method to help orthodontists and maxillofacial surgeons unfamiliar with CBCT interpretation to identify the severity of MCI and predict the best type of treatment intervention.

Recommendations are to test the reliability, reproducibility, and validity of this method in further studies, as well validate this prediction model on different populations prospectively to evaluate the true performance of this model as a simple new guide for maxillary impacted canine diagnosis and treatment prediction tool.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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