ijlpr 2023; doi 10.22376/ijlpr.2023.13.2.L211-218

International Journal of Life science and Pharma Research

ISSN 2250-0480

Research Article

Orthodontics

Impacted Canines Localization and Its Impact on Dental Arch in Orthodontic Patients: A Novel CBCT Clinical Study

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Abstract: Although impacted canines concerning dental arch have been analyzed in prior studies. However, there is a lack of evidence to analyze the impact of impacted canines on dental arch characteristics using cone beam computed tomography (CBCT) models; therefore, knowing the impact of impacted canines on the dental arch can enhance awareness, contribute knowledge, and aid clinicians in managing impacted canine cases. Hence, it is critical to emphasize the strategies of proper diagnosis and interception for this clinical condition prior to any orthosurgical treatment procedures. This study aimed to analyze the impact of impacted canines on dental arch characteristics in orthodontic patients using CBCT. The method used was the review of clinical records of 350 patients with impacted canines who had CBCT scans and visited the dental clinics for orthodontic treatment pertaining to their arch by dividing them into a control group and a study group. The results revealed a significant relationship based on the dental arch dimension; inter first premolar width (IPW) (P = 0.012), inter first molar width (IMW) (P = 0.010), arch length (AL) (P = 0.041), palatal height (PH) (P = 0.019), and palatal height index (PHI) (P = 0.020). The article concludes that patients with impacted canines had significant changes in dental arch dimension compared to the control group. Dental arch dimensions were significantly deficient, with a higher palatal vault seen in impacted canine patients. The anatomical position of impacted canines has an effect on the dental arches and adjacent anatomical structures. These three-dimensional (3D) findings may provide clinical reference data for impacted canines and provide a valuable basis for delivering information and education on impacted canines assessment and treatment. CPD/Clinical Relevance: Canine impactions are common during routine examinations. Understanding the influence of impacted canines on the dental arch will help clinicians manage impacted canine patients.

Keywords: Canines, Impaction, Orthodontics, Patients, CBCT, Dental arch

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Received On 06 April, 2022
Revised On 13 May, 2022
Accepted On 21 July, 2022
Published On 01 March, 2023

Funding This research did not receive any specific grant from any funding agencies in the public, commercial or not for profit sectors.

Citation Alfarra Y. H. Y., Noorani T. Y., Asif J. A., W. Ahmad W. M. A., and Rajion Z. A. Impacted canines localization and its impact on dental arch in orthodontic patients: A novel CBCT clinical study. Int. J. Life Sci. Pharma Res.2023;13(2):L211-218. http://dx.doi.org/10.22376/ijlpr.2023.13.2.L211-218.

1. INTRODUCTION

Canine teeth are esthetically the most dominant teeth, which can present a smile as either holy or evil. They define the mouth's corner, are involved in the facial esthetic smile, maintain occlusal stability, and design the shape of the dental arch.[1] The permanent maxillary canine is the most commonly impacted tooth after the third molar.[2,3] Permanent canines serve as the foundation of the dental arches. It is located in the corner of the dental arch, which is crucial for smile esthetics because they form the canine eminence to protect the upper lip and the alar base.[4,5] It aids in maintaining dentition by assisting with disarticulation during masticatory load and lateral motions, as well as functional occlusion and directing the jaw into the proper position. It is known as cuspid protection.[6,7] It also helps in chewing and ripping food. It is one of the most significant outstanding abutments for prosthetic replacement of other maxillary teeth due to its root volume and length.[8,9] Impacted canines provide multiple aspects for practitioners since they compromise tooth exposure as well as movement for esthetical and functional concerns. Consequently, loss of impacted canines prematurely can result in esthetic, phonetic, malocclusion, and jaw functioning/growth alterations.[10-13] Canine impaction can compromise tooth alignment of adjacent teeth, shortening dental arches and enhancing the possibility of follicular cyst formation and recurring infections.[14,15] The physical pressure from a greater degree of canine displacement might be associated with severe incisor root resorption, which is irreversible damage that can lead to tooth loss.[2,9] In the presence of impacted canines, the morphometric variation in arch dimensions can be regarded as a clinical aspect.[15] The optimal facial harmony is considered the result of well-defined underlying dentofacial characteristics.[16] With the advancement of orthodontic knowledge and the increase in the number of patients, it is crucial to understand the changes in adult craniofacial structures.[3,4] The specialty of orthodontics is filled with various challenges that require careful diagnosis and planning; one of these challenges involves impacted canines.[5] Canine impaction hypotheses are divided into two categories: genetics and guidance. The root of the adjacent lateral incisor guides the canine to erupt properly into the arch. However, if the following lateral incisor is congenitally absent or peg-shaped, there appears to be no direction for the canine to follow. As a result, the canine will not erupt. This is referred to as the guidance theory.[5,17] Genetic factors such as ethnicity, gender, agenesis of adjacent teeth, aplasia, and supernumerary teeth were assumed to be a result of genetic and environmental multifactorial inheritance, according to genetic theory.[5,18,19] Since the impacted canines are adjacent to vital anatomical structures, a thorough radiographic evaluation to determine the position of impacted canines is required before any treatment planning. A CBCT scan can clearly indicate its location for a clinician.[3] Orthodontists and dental professionals have used CBCT to diagnose impacted teeth because it eliminates the superimpositions inherent in two-dimensional (2D) imaging and offers several advantages over conventional computed tomography (CT), including faster scanning, image precision, user-friendly software, reduced exposure time, and low cost.[3,4,12,18,19] Accurate diagnosis is required for both efficient treatments of impacted canines and the collection of more scientific data. IMW and AL were deficient in patients with canine impaction based on Fattahi et al.[20] However, this investigation determined dental arch using 2D analysis, which did not provide enough information on the dental arch in 3D, which is required to obtain more scientific data. Knowing this relationship aids in managing impacted canines and determines whether the arch dimension in impacted canine patients differs from the control group and contributes to the science of anatomical structures. In comparison to prior approaches, CBCT is particularly useful in analyzing the impacted canines and adjacent structures. Its technology has the advantages of high resolution, high efficiency, and low radiation dosage.[3,4] To the best of the authors' knowledge, there are no published or accessible articles/studies available discussing the relationship between canine impaction and dental arch characteristics using CBCT models.[20-22] Thus, this study aimed to analyze the impact of impacted canines on dental arch characteristics in orthodontic patients using CBCT.

2. MATERIALS AND METHODS

2.1 Ethical Approval and Study Sample

The study was approved by the Human Research Ethics Committee of Universiti Sains Malaysia (USM) (USM/JEPeM/19070385). CBCT images of 350 patients aged 15 to 50 years with a full permanent dentition, who attended dental clinics for orthodontic treatment at Hospital Universiti Sains Malaysia (HUSM), Malaysia, from January 1st, 2010 to November 30th, 2020, were recruited based on inclusion and exclusion criteria.

2.2 Consent to Use Patient Data

All patients undergoing orthodontic treatment at the orthodontic unit signed the consent form indicating that the patient's data could be used for future research purposes.

2.3 Data Extraction

Information, such as age, gender, type of impacted canine, and dental arch characteristics, was extracted from the patient files who had CBCT using Microsoft Excel spreadsheets (Microsoft® Excel® MSO, Redmond, WA, USA).

2.4 Patient Recruitment and Allocation

The samples were gathered from the records by accessing each CBCT image independently under a code number unique to each subject. The CBCT image was then examined on a 15.6-inch full high definition flat screen HP monitor (HP Envy 10TX, HP Inc., Round Rock, Texas, USA), running Microsoft Windows® 11 (Microsoft Corp., Redmond, WA, USA), by the author Dr. (Y.H.Y.A.) with more than five years of experience in CBCT using 3D software analysis (Planmeca Romexis®, Finland) (Figure 1).[23]

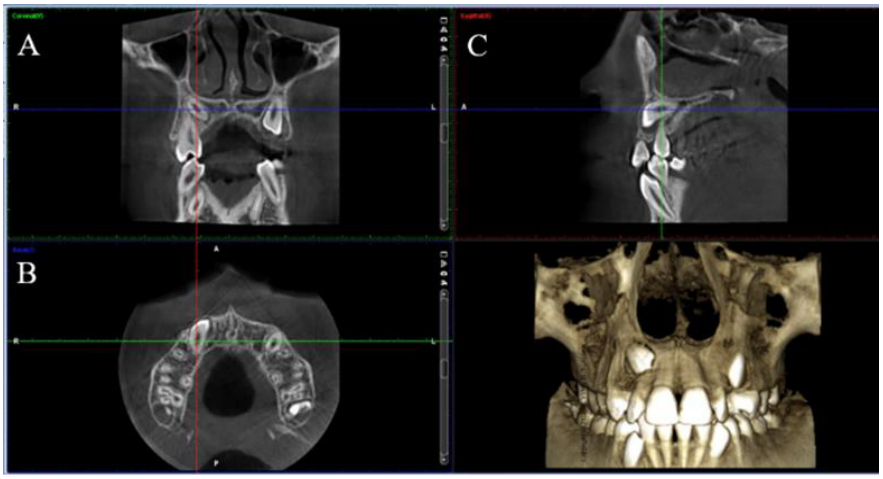

Fig. 1: The three-dimensional reconstructed image acquired from raw CBCT data; (a) Coronal view, (b) Axial view, and (c) Sagittal view.

2.5 Inclusion and Exclusion Criteria

Orthodontic treatment or previous extractions of adjacent teeth, a history of jawbone trauma, cleft lip/palate, or other craniofacial anomalies were excluded. Furthermore, patients exhibiting low-quality CBCT scan grade 2 with any distortion or loss of clarity were also excluded. A CBCT grade of 1 indicates "acceptable," whereas a grade of 2 represents "unacceptable".[24]

2.6 Operational Definitions and Procedures

Based on radiographic examination, an impacted canine is an intraosseously positioned canine that fails to erupt at its appropriate site in the dental arch.[25]

2.6.1 *Impacted canines related to the arch dimension*

The arch dimension includes arch width, length, and height. Arch width: Figures 2 and 3 describe the IPW and IMW measurements.[25,26]

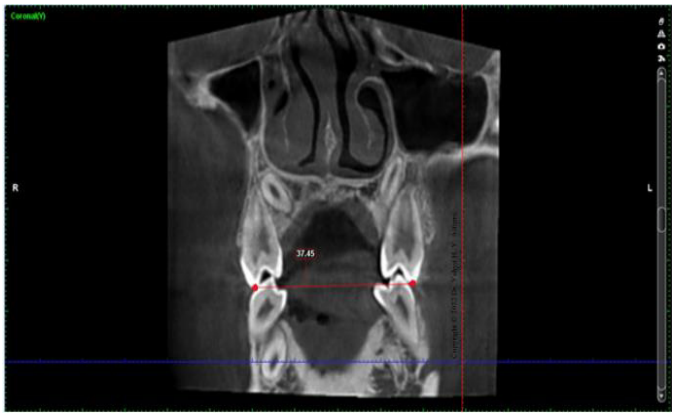

Fig. 2: A CBCT image shows the distance of the inter first premolar arch width measurement from the buccal cusp tip of one side to the buccal cusp tip of the contralateral side in the coronal view.

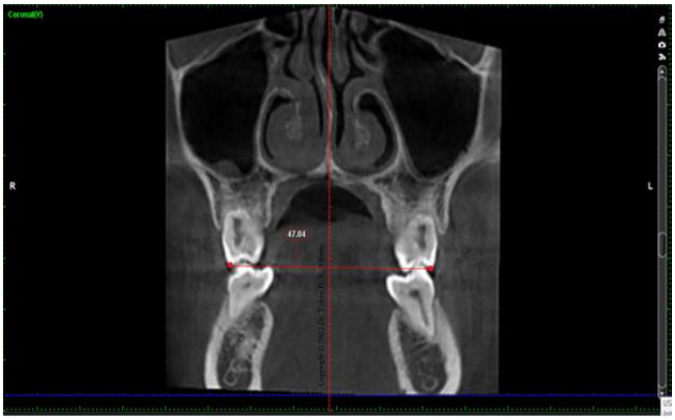

Fig. 3: A CBCT image shows the distance of the inter first molar arch width measurement from the mesiobuccal cusp tip of one side to the mesiobuccal cusp tip of the contralateral side in the coronal view.

Arch length: The arch length is explained in Figure 4.[26]

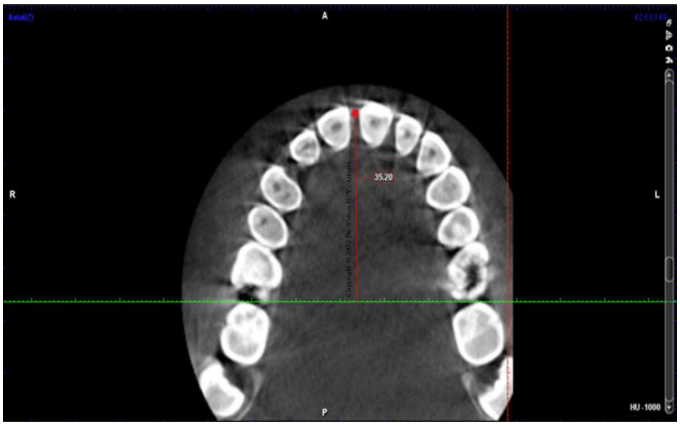

Fig. 4: A CBCT image shows the reference lines for measuring arch length, the perpendicular distance from the tangent drawn on the distal aspect of the first permanent molar to the contact point of right and left central incisor teeth in the axial view.

Palatal height analysis: Figure 5 describes the palatal height measurement.[25,26] PHI was computed by dividing the PH by the IMW using the following formula: PHI = PH x 100/IMW.[20]

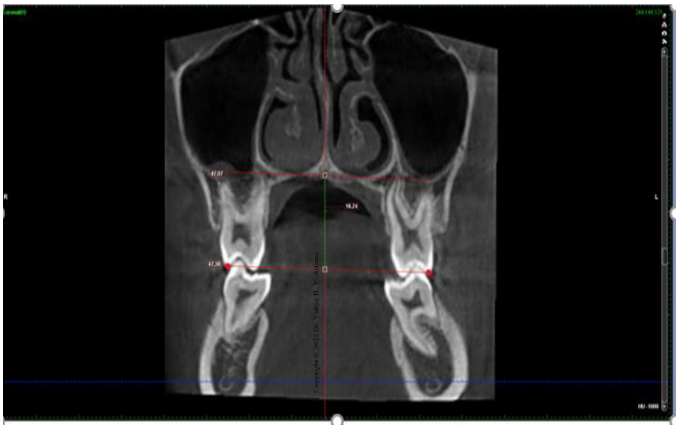

Fig. 5: In a coronal view of a CBCT scan, a horizontal line was drawn through the nasal floor perpendicular to the vertical skeletal line to determine the distance between this horizontal line and the bilateral mesiobuccal cusp of the inter first molar width to determine the palatal height measurement.

2.6.2 *Impacted canines related to the dental arch form*

The arch form was evaluated by drawing a dental central line passing through the pulp chamber of all teeth in the axial view (Figure 6).[25,26] The arch forms and dimensions of the study and control groups were compared. The landmarks of interest were digitized, and transverse measurements were recorded after image acquisition.

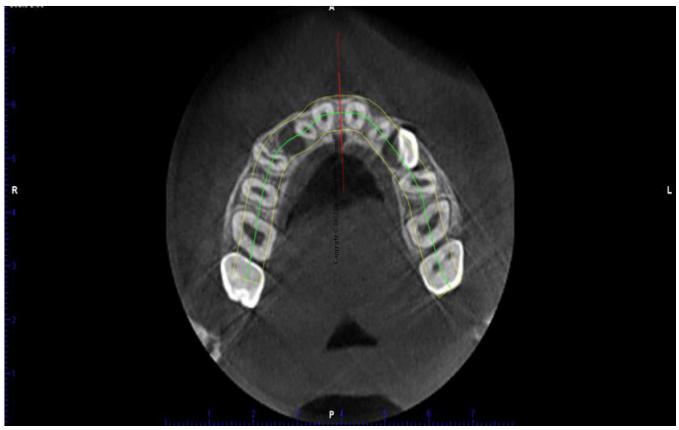

Fig. 6: A CBCT image shows the reference lines for determining the arch form in the axial view.

2.7 *Statistical Analysis*

SPSS statistics version 27.0 was used to analyze the data (IBM SPSS Statistics, Armonk, NY, USA). The significance level was set at $P < 0.05$. The reliability of numerical measurements of IPW, IMW, AL, PH, and PHI was assessed using Intraclass Correlation Coefficient (ICC). Kappa statistics were used to measure the level of agreement for the categorical variables. Inter-rater reliability of parameters was excellent, with a high level of agreement of 0.98. Intra-rater reliability of all parameters was also excellent, with high agreement values: IPW 0.95, PH 0.96, AL 0.91, and PHI 0.97.

3. RESULTS

Table 1 shows the relationship between the impacted canines and the dental arch form and dimension. Fisher's exact test and Pearson's correlation coefficient were employed to investigate this relationship. The ovoid arch form 123 (89.2 %) was the most common for maxillary and mandibular arches. Furthermore, Pearson's correlation coefficient analysis revealed a significant relationship between the impacted canines and the dental arch dimension IPW ($P = 0.012$), IMW ($P = 0.010$), AL ($P = 0.041$), PH ($P = 0.019$), and PHI ($P = 0.020$). Dental arch dimensions were deficient in impacted canine patients, considered a local reason for canine displacement.

Table 1: The relationship between the impacted canines and the dental arch form and dimension.

Variables Impacted canines	Dental arch form, *n* (%)			*P*-value
	Ovoid shape	Tapered shape	Square shape	
Total	123 (89.2 %)	5.00 (3.60 %)	10.0 (7.20 %)	0.347

Dental arch dimension						
	Impacted canines	IPW	IMW	AL	PH	PHI
Impacted canines	1.00					
IPW (mm)	0.012*	1.00				
IMW (mm)	0.010*	0.001*	1.00			
AL (mm)	0.041*	0.001*	0.001*	1.00		
PH (mm)	0.019*	0.001*	0.001*	0.001*	1.00	
PHI (%)	0.020*	0.001*	0.001*	0.038*	0.027*	1.00

* Significant *P*-value.

Table 2 compares the dental arch form and dimension between the study and control groups. There were 175 subjects in the study group and 175 subjects in the control group. The Chi-square test revealed an insignificant difference in the relationship between the impacted canines and both groups' dental arch form. The ovoid arch form was the most common in both the study and control groups, accounting for 159 (90.8 %) and 163 (93.1 %), respectively. An independent t-test revealed a significant difference ($P = 0.001$) in comparing the dental arch dimension between both groups. IMW (2.50 mm), PHI (2.40 %), and PH (2.30 mm), followed by AL (2.20 mm) and IPW (1.90 mm), respectively. IPW, IMW, and AL were significantly deficient and narrower in impacted canine patients, with a higher palatal vault than in the control group.

Table 2: Comparison of the dental arch form and dimension between the study and the control groups.

Dental arch form				
Variables	Study group, *n* (%)	Control group, *n* (%)	X^2 (df)	*P*-value
Ovoid shape	159 (90.8 %)	163 (93.1 %)	0.05	0.824
Tapered shape	6.00 (3.49 %)	7.00 (4.05 %)	0.07	0.782
Square shape	10.0 (5.71 %)	5.00 (2.85 %)	1.66	0.197
Total	175 (100 %)	175 (100 %)		

Dental arch dimension					
	Study group Mean (S.D)	Control group Mean (S.D)	Mean Differences (95% CI)	*t*-statistic	*P*-value
IPW (mm)	40.8 (0.72)	42.7 (0.62)	-1.90	-07.1	0.001*
IMW (mm)	50.6 (0.80)	53.1 (0.63)	-2.50	-04.6	0.001*
AL (mm)	36.6 (1.94)	38.8 (1.79)	-2.20	-03.9	0.001*
PH (mm)	19.7 (1.10)	22.0 (0.99)	-2.30	-15.8	0.001*
PHI (%)	39.1 (1.86)	41.5 (0.96)	-2.40	-15.1	0.001*

* Significant *P*-value.

Table 3 shows the distribution of impacted canines. Canine impaction was most common in females, accounting for 103 cases, followed by males (72.0). Females had higher unilateral canine impactions (97.0) than males (47.0). Furthermore, bilateral canine impactions in females were more common (20.0) than in males (11.0).

Table 3: Distribution of impacted canines.

Variables	Number	Age Range	Impacted canines		
			Unilateral	Bilateral	Total
Male	72.0	15-50	47.0	11.0	58.0
Female	103	15-50	97.0	20.0	117
Total	175		144	31.0	175

4. DISCUSSION

As far as the authors are aware, this is the first study to investigate the relationship between impacted canines and dental arch characteristics using CBCT. The author's original research generated a useful clinical reference database for orthodontic assessment and diagnosis. This study used CBCT and analyzed it with 3D software, resulting in new findings that were not previously highlighted. It has also contributed to the science of anatomical structures and enhanced awareness of impacted canines. The anatomical position of impacted canines was presented in 3D, influencing the surrounding structures and dental arch features. Overall, it benefits the treatment planning of impacted canine cases. Canines serve an important role in both esthetic smiles and functional occlusion. Prior to any orthosurgical treatment procedures, it is essential to emphasize the strategies of proper diagnosis and interception for this clinical condition.[5,19] In clinical orthodontics, identifying dental arch form is critical for esthetics and long-term occlusal stability by preserving the original arch form and dimension.[17] The current investigation found insignificant differences between impacted canines and dental arch forms. A possible explanation for this finding could be attributed to the inclusion criteria, method of the study, racial and genetic variations.[27] These results agree with Refaat and El-Desouky's findings, who reported no difference in the shape of the maxillary arch between genders.[26] Moreover, the results revealed significant differences between the study and control groups. In impacted canine patients, dental arch dimensions were deficient. These findings are consistent with Cacciatore et al.,[28] who observed that in the displaced canine group, both AL and IMW were reduced. However, this study did not report the IPW and PH arch dimension measures, and the impacted canine was diagnosed using a panoramic radiograph. AL and IMW were also measured with the dental cast. Even if digital models were obtained by scanning plaster casts, their applicability to provide reliable volumetric data seems unfeasible. Similar evidence was done by McConnell et al.[21] examined maxillary width. It was found that impacted canines' patients had maxillary transverse deficiencies in ICW of their dental arches. However, the impacted canine was diagnosed using a panoramic radiograph, and the ICW was measured using a dental cast which is insufficient information for evaluating the impacted canines. Furthermore, this method of measuring ICW was unreliable and subjective, according to Langberg and Peck,[22] because the measurement points were selected by visual observation. They did not determine the exact position of impacted canines. On the other hand, CBCT analysis in the current study allows for evaluating the specific location of the points or regions of impaction in 3D. Although prior articles on this subject have been published, their conclusions are inconclusive and often contradictory.[21,22] No prior studies have investigated in detail the relationship between impacted canines and dental arch dimensions using CBCT models. Other authors who studied dental arches in impacted canines did not explore PHI measurement. Therefore, the author added a missing piece to the palate morphology and maxillary arch puzzle in impacted canine subjects. The morphometric variation in arch dimensions is a clinical factor related to impacted canines.[29]

Orthodontic study models are an essential component of orthodontic records. However, CBCT models were used instead because of the disadvantages of long-term storage for study models, such as displacement of the model, friction, damage, distortion, and loss of some details, which may cause a problem with measurements. CBCT models, on the other hand, are a valid and reliable tool for dental arch measurements,[3,19] as the radiographic image is digitized and remains the same as the first day it was obtained; hence all measurements were carried out on radiographs rather than models. These findings of the current study are also supported by the suggestion from Refaat and El-Desouky,[26] who reported that McConnell et al. used measurements derived from stone cast to assess the relationship between discrepancies in the maxillary morphology and maxillary impacted canines, but the results of these studies were often contradictory and controversial.[26] More female subjects than male subjects in the current study. These findings are similar to the findings of Ngo et al., who reported that females dominate males in the American population.[29] These results contradict Hsu et al. finding, who stated that the female to male ratio was 1:1.8.22.[30] Unilateral canine impactions were more common than bilateral impactions, which is consistent with previous research.[27,30] The findings of this study were similar to those reported in other studies, while the dissimilarities were attributed to inclusion criteria, study method, and ethnic and genetic variances.[19] The treatment of impacted canines is influenced by the type of impaction, patient's age and surgical procedure, overall oral health, spacing and crowding, and related complications such as cystic degeneration and adjacent tooth resorption. Interceptive treatment, surgical exposure, orthodontic alignment, or autotransplantation are all options for treatment.[31] Ericson and Kurol[31] recommend deciduous canine extraction as the treatment of choice to treat palatally impacted canines in patients aged 10 to 13 years old and in cases when adequate space available. If the deciduous canine is retained and there are no other major malocclusions, some patients may refuse to consider treatment.[32] A CBCT image allows a clinician to establish the location of impacted canines, teeth position, length, orientation, related structures, and dental arch measures and choose the optimum therapy strategy to minimize surgical trauma to the surrounding hard and soft tissues.[3,4,19] Therefore, the biomechanics involved in canine retraction with fixed orthodontic appliances are reduced. The advantages of a CBCT image ensure an optimal radiography strategy for detecting the impaction and the surrounding structures.[3,17] The CBCT digital acquisition system is useful in various dental specialties, including orthodontics, oral diagnosis, oral surgery, endodontics, implantology, and others.[3,5] The radiation risk of using CT is exceedingly doubtful.[4] As a result, the primary advantage of CBCT over a CT scan is the reduced radiation dose.[18] The use of CBCT can help in the correct and timely diagnosis and the best treatment intervention.[5] This was in agreement with research that found panoramic images have proven unreliable in establishing the precise location of impacted canines.[28] Furthermore, CBCT has been proven by maxillofacial surgeons and orthodontists to be superior to other radiological techniques for visualizing the craniofacial area, as

well as a useful tool for identifying the position of ectopic eruption teeth.[3,4,12,30,33] In terms of anatomical differences, CBCT has also shown superior results for identifying the temporomandibular joint (TMJ) or detecting cleft lip and palate, as well as diagnosing permanent canines.[4,34] Furthermore, Eslami et al.[4] and Zufia et al.[3] indicated that CBCT is the superior imaging choice in determining the impacted canine position. It is required to develop a successful treatment plan even though it might be costly. CBCT was found to be more reliable than panoramic radiographs in this study for localizing impacted canines, consistent with the findings of previous studies.[19,26] In this study, repeated evaluations revealed no significant difference between two registrations for both raters and did not affect measurement reproducibility. These findings are consistent with Ngo et al.[29] The main factors in enhancing landmark identification are experience and calibration. Thus, the author conducted periodic calibrations with the expert operators using a different set of CBCT images.[23] In addition, a single expert operator acquired all of the images to eliminate discrepancies in the results caused by differences in the operator's skills.[3] This study had certain unique characteristics. First, all identified cases of impacted canines from CBCT scans were included in this study to represent different types of impacted canines, as a larger sample size presented more accuracy and precision.[35] In comparison to previous studies that obtained a smaller sample size, Fattahi et al. (106 subjects),[20] and Refaat and El-Desouky (90 participants).[26] In addition, the current study established a new clinical reference database for assessing and diagnosing impacted canines based on CBCT. In this light, a 3D analysis can improve diagnosis and treatment planning for impacted canine patients.[30,33] Furthermore, the current findings provided an additional clinical application by correlating interceptive techniques to enhance arch perimeter as preventive protocols for misplaced maxillary canines. A systematic review study validated cervical-pull headgear (HG) and rapid maxillary expander (RME) as orthodontic treatments for displaced maxillary canines.[4,8] The effectiveness of the consistency between the outcomes of the reduction of IMW, AL, and PHI and the strength of protocols that enhance arch dimension was raised. The present study provides the evidence base for future extended research that will include multicenter and analyze the etiology of buccal/palatal impactions or bilateral/unilateral, which could assist practitioners in understanding and facing this phenomenon.

5. CONCLUSIONS

Sound knowledge of the canine morphology is essential for documenting and simplicity of interdisciplinary communication among clinicians. The impacted canines appeared to be related to dental arch dimension measurements. Dental arch dimensions were narrower, with a higher palatal vault in impacted canine patients than in the control group. The locations of impacted canines vary widely in three planes, and the resorption of adjacent permanent incisors is common. The inclusion of this study in a clinical setting would save clinicians' time in pre-operative preparation and patient management costs. The current study offered a valuable resource for information on impacted canines. This will be a multidisciplinary resource for students, researchers, and clinicians in the dental field, with a particular focus on orthodontics.

6. INSTITUTIONAL REVIEW BOARD

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Human Research Ethics Committee of USM (USM/JEPeM/19070385).

7. AUTHORS' CONTRIBUTIONS

Dr. Yahya H. Y. Alfarra (Y.H.Y.A.) conducted the study as part of the PhD program, developed the concept and idea, managed the data collection process, performed methodology, carried out project administration activities, and wrote and submitted the manuscript . The article processing charges were fully paid by Dr. (Y.H.Y.A.). The authors reviewed the study report.

8. CONFLICTS OF INTEREST

There are no conflicts of interest.

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