Original Article

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Quick Response Code:

Website:
www.jorthodsci.org

DOI:
10.4103/jos.jos_129_23

Evaluation of maxillary transverse dimensions in individuals with a unilaterally impacted canine

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Submitted: 10-Jul-2023
Revised: 10-Jan-2024
Accepted: 15-Jan-2024
Published: 16-Feb-2024

Abstract

INTRODUCTION: The aim of this study was to investigate the maxillary width within individuals with a unilaterally impacted maxillary canine and to determine any association between the impacted canine location and some canine-related variables.

METHODS: A cross-sectional analytical study using a split-mouth design included 22 CBCTs of individuals with unilaterally impacted maxillary canines (a total of 44 sides). The maxillary width was measured and compared in both impacted and non-impacted sides at various levels: basal, alveolar, and dental. The following canine-related variables were analyzed and compared with impaction location: impacted canine angulation, cusp tip distance from the occlusal plane, type of impaction (vertical or horizontal), presence of root resorption, deciduous teeth, or adjacent teeth transposition. Significance was considered at $P < 0.05$.

RESULTS: There was a significant reduction in maxillary width on the impacted side at the following levels: maxillary first premolar alveolar crest in both coronal and axial sections, dental width measured from the central fossa of maxillary first molar to the midline, and width measured from the canine cusp tip to the midline. Moreover, the distance from the palatally impacted canine cusp tip to the occlusal plane was statistically significantly lower (7.6 ± 1.5 mm) compared to buccal (10.8 ± 3.3 mm) and mid-alveolus (12.0 ± 3.9 mm) impaction, (*P* values = 0.02).

CONCLUSIONS: There was a significant association between canine impaction and reduction in the maxillary width at least on the dental level. The palatally impacted canine cusp tip was significantly closer to the occlusal plane compared to the buccal and mid-alveolar impaction.

Keywords:

CBCT, impacted canine, maxillary width

Introduction

An impacted tooth is defined as the failure of a tooth to erupt within its appropriate time and position in the dental arch.[1,2] The prevalence of maxillary canine impaction has been reported to be 0.2%–2.8% in the general population, which is considered to be the second most common impacted tooth.[3–5] Palatally impacted canine occurs 3–6 times higher than the buccally impacted canine and is more common in females than males.[3–6] The possible complications related to canine impaction include root resorption of adjacent teeth, canine ankylosis, and follicular cyst formation.[7–10] The etiology of canine impaction depends on the location of impaction. For palatally impacted canines, the genetic theory and the guidance theory have been proposed.[11–13] However, dental crowding has been related more to buccally impacted canines.[14,15] In addition to these theories, several studies have been conducted to discover the relationship between maxillary transverse width and canine impaction by utilizing cone beam

How to cite this article: Alshalawi IA, Alnahad DM, Ardah HI, Aboelmaaty WM, Alrejaye NS. Evaluation of maxillary transverse dimensions in individuals with a unilaterally impacted canine. J Orthodont Sci 2024;13:6.

computed tomography (CBCT).[3,11,14,16] According to Yan *et al*.,[16] maxillary skeletal and dental transverse widths were found to be deficient in individuals with buccally impacted canines.[16] Similarly, Arboleda-Ariza *et al*.[14] found a deficiency in the maxillary skeletal transverse width with unilateral and bilateral impacted maxillary canines.[14] On the contrary, Hong *et al*.[11] reported that the maxillary skeletal and dental transverse widths had no relation with palatally impacted canines.[11] These studies used different measurements to evaluate maxillary transverse width. Moreover, the implementation of a split-mouth design, which is used to compare the impacted side with the non-impacted one within the same individual, is limited. D´ Oleo Aracenta *et al*.[3] implemented split-mouth design and showed a deficiency in the measurements from maxillary first premolars to the mid-palatine raphe in the axial section of the CBCT image on the impacted side compared with the non-impacted side.[3]

It has been reported that the possibility of canine impaction increases in individuals with maxillary transverse width discrepancies,[3,17] and there is a lack of unified measurements in the literature with only a few and inconsistent reports published about the maxillary transverse width in individuals with impacted canines. Therefore, the present study was designed to further investigate the skeletal and dental maxillary transverse widths by using CBCT in individuals with a unilateral impacted maxillary canine (split-mouth design), analyze and compare the impaction location (palatal vs. buccal vs. mid-alveolus) with the following variables: impacted canine angulation, cusp tip distance from the occlusal plane, type of impaction (vertical or horizontal), presence of root resorption, presence of deciduous teeth, and presence of adjacent teeth transposition.

Material and Methods

This is a cross-sectional analytical study based on radiographic records of individuals with a unilaterally impacted maxillary canine who had CBCT taken previously for diagnostic or treatment purposes. Ethical approval for this study was obtained from the institutional review board (IRB) office at King Abdullah International Medical Research Center, Ministry of National Guard Health Affairs, Riyadh, Saudi Arabia (# NRC21R/043/01). All individuals who met our inclusion criteria with CBCTs acquired between October 2017 and July 2022 were included in our study, which consisted of 22 Saudi individuals (12 females and 10 males), with an average age of 15.8 ± 3.1 years ranging from 12 to 27 years. Twelve of the impacted canines were located on the right side, whereas 10 were located on the left. Inclusion criteria were the initial pre-orthodontic CBCT scans available in the orthodontic clinic at King Saud bin Abdulaziz University for Health Sciences and Ministry of National Guard Health Affairs in Riyadh, Saudi Arabia, and had a unilaterally impacted maxillary canine.

All scans were exported from the Planmeca ProMax 3d Mid CBCT machine. Exposure protocols were variable with KVp ranges between 90 and 120 according to FOV. Volumetric scans of individuals with craniofacial anomalies, taken after initiating orthodontic treatment, had poor quality (blurred), or not showing all needed landmarks were excluded. Raw DICOM files were imported into OnDemand 3D App software (version 1.0.10; Cybermed Inc., Seoul, Korea) and used for re-orientating the CBCT volumes. The orientation of the CBCT 3D volume was adjusted by a radiology expert who did the head position correction in the three orthogonal planes by using fixed anatomical landmarks for symmetrical re-alignment of data. This stage is very crucial as it determines whether the following cross-sectional and trans-axial pictures will be aligned perpendicular to the structure of interest. The re-orientation process was accomplished by having the occlusal plane parallel to the floor and the mid-sagittal plane perpendicular to the floor. The coronal section orientation was verified using the nasal floor mediolaterally, and the mid-sagittal plane was considered the default guideline for midline localization. To compare the impacted side with the non-impacted side by using both axial and coronal views, the palatal plane from anterior nasal spine to posterior nasal spine (ANS to PNS) was used as the midline in axial cuts, while a vertical line from ANS was defined as the midline in coronal cuts. After proper re-orientation and adjustment to the volume, some measurements were performed using the digital ruler tool in the multiplanar reconstruction (MPR) module in the software. The measurements for five randomly selected scans were collected twice at 2-week intervals to test the intra-examiner reliability. Previous CBCT studies in the literature that evaluated the impacted maxillary canines and their relation to maxillary width were reviewed, and the significant variables were collected to be investigated further in this study.[3,11,14,16,18] Some of the measurements were modified for the split-mouth design used in the present study. The measurements to analyze the maxillary transverse width included the following:

Measurements performed on CBCT coronal sections

- Maxillary first molar basal width (MBW): A line measured in millimeters from the J point of the maxilla to the midline, where the midline was defined as the mid-sagittal plane or a vertical line from ANS [Figure 1].
- Maxillary first molar alveolar width (MAW): A line measured in millimeters from the occlusobuccal alveolar crest to the midline [Figure 1].

- Maxillary dental width (MDW): A line measured in millimeters from the central fossa of the maxillary first molar to the midline [Figure 1].
- Maxillary first premolar basal width (PBW): A line measured in millimeters from the outer edge of the maxillary base to the midline [Figure 2].
- Maxillary first premolar alveolar width- coronal section (PAWc): A line measured in millimeters from the occlusobuccal alveolar crest to the midline [Figure 2].

Measurements performed on CBCT axial sections

- Maxillary first premolar alveolar width- axial section (PAWa): A line measured in millimeters from the alveolar crest located mesial to the maxillary first premolar to the midline, which was defined as the mid-sagittal plane or the line from ANS to PNS (ANS = primary reference) in the axial cut taken at the level of the concerned alveolar crest [Figure 3].
- Maxillary canine cusp tip to the midline (CCT-ML): A line measured in millimeters from the maxillary canine cusp tip to the midline [Figure 4].

Impacted canine-related variables

The location of the impacted canine, whether it is palatally, buccally, or mid-alveolar, was determined based on the position of the impacted canine cusp tip relative to the adjacent teeth in the CBCT axial section. The following variables were determined and compared with the maxillary impacted canine location (palatally, buccally, and mid-alveolus) to identify any significant association:

- Impacted canine cusp tip to the occlusal plane (CCT-OP): Measured in the 3D module sagittal view as the perpendicular distance in millimeters from the maxillary impacted canine cusp tip to the occlusal plane, where the occlusal plane was defined as a line from the mesiobuccal cusp tip of the maxillary first molar to the incisal edge of the maxillary central incisor [Figure 5].
- Impacted canine angulation to the midline (CA-ML): Measured in the 3D module coronal view as an angle formed by the long axis of the maxillary impacted canine and the midline of the maxilla, where the maxillary midline was defined as a vertical line from ANS [Figure 6].
- Impacted canine angulation to the lateral incisor (CA-LI): Measured in the 3D module as an angle formed by the long axis of the maxillary impacted canine and the long axis of the maxillary lateral incisor; the 3D volume was adjusted mediolaterally to allow good visibility of both the canine and lateral incisor concurrently [Figure 7].
- Type of canine impaction (vertical or horizontal): Vertical impaction was assigned if the impacted canine was vertically inclined and covered with soft or bony tissue, while horizontal impaction was assigned if the impacted canine was horizontally inclined and covered with soft or bony tissue. Horizontal angulation was assigned when the impacted canine angulation was less than 45° to the occlusal plane. This was analyzed in the 3D module.
- Presence of root resorption: classified based on the system proposed by Ericson and Kurol: Root resorption was assigned when at least half of the dentin thickness was gone.[9] The roots of adjacent teeth were evaluated from the cementoenamel junction all the way to the apex axially, and the most severe dentin reduction was considered.

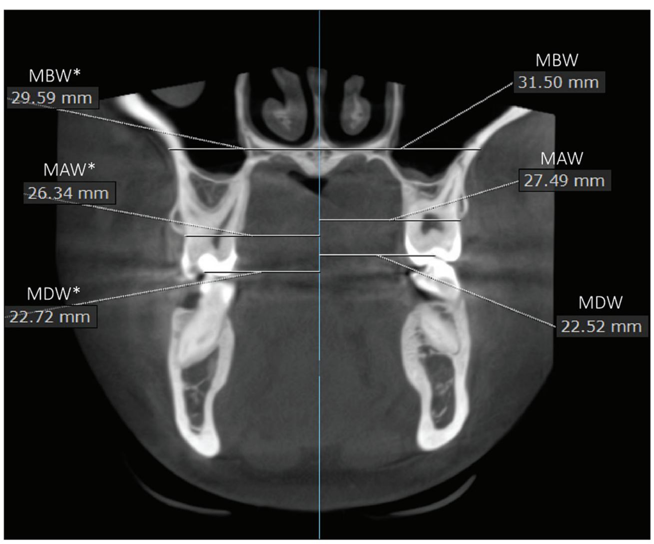

Figure 1: CBCT coronal section at the level of the maxillary first molars. MBW: Maxillary first molar basal width. MAW: Maxillary first molar alveolar width. MDW: Maxillary dental width. * Indicating the non-impacted side. Vertical line = the midline, a perpendicular line from ANS

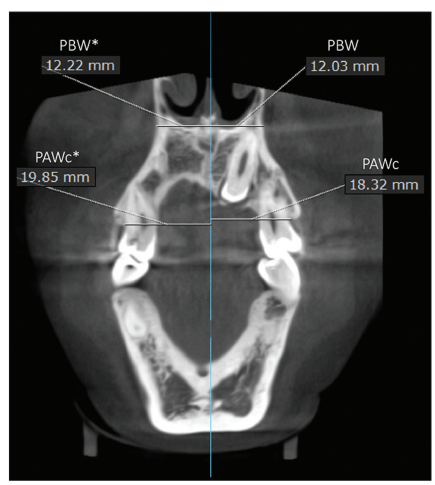

Figure 2: CBCT coronal section at the level of the maxillary first premolars. PBW: Maxillary first premolar basal width. PAWc: Maxillary first premolar alveolar width. * Indicating the non-impacted side. Vertical line = the midline, a perpendicular line from ANS

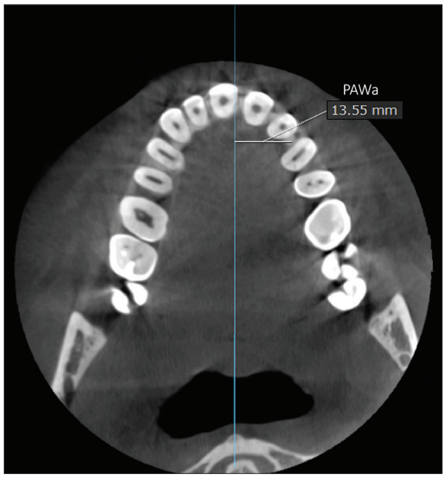

Figure 3: CBCT axial section at the level of the alveolar crest mesial to the first premolar. Maxillary first premolar alveolar width (PAWa) measured in the axial section from the alveolar crest mesial to the first premolar at the impacted side to the midline. A similar method was utilized for the non-impacted side. Vertical line = the midline, a line from ANS to PNS (ANS = primary reference)

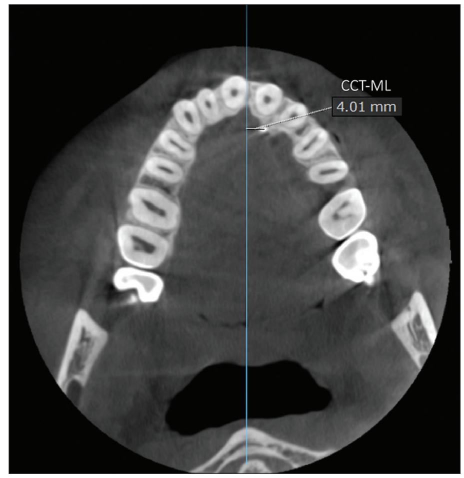

Figure 4: CBCT axial section at the level of the canine cusp tip. The measurement (in millimeters) was taken from the impacted maxillary canine cusp tip to the midline (CCT-ML). A similar method was utilized for the non-impacted side. Vertical line = the midline, a line from ANS to PNS (ANS = primary reference)

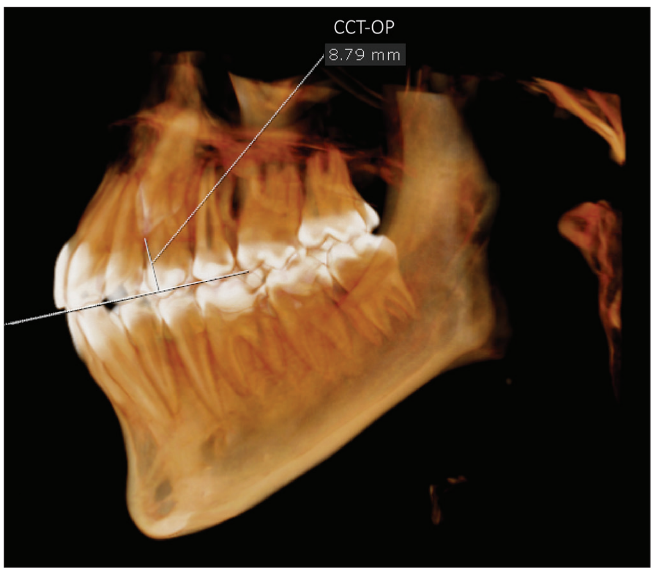

Figure 5: CBCT 3D module used to measure the impacted canine cusp tip to the occlusal plane (CCT-OP), the perpendicular distance (in millimeters) from the maxillary impacted canine cusp to the occlusal plane

- Presence of maxillary deciduous canine at the impacted canine side.
- Presence of adjacent teeth transposition: central incisor, lateral incisor, first premolar, or second premolar.

For testing intra-examiner reliability, the systematic error was calculated using an intraclass correlation coefficient (ICC). Means, medians, and standard deviations (SD) of the observed maxillary transverse width (in millimeters) were calculated for the two groups (impacted and non-impacted) to describe their distributions. The two groups were compared using paired sample *t*-test or Wilcoxon signed rank test as appropriate to account for the within-individual

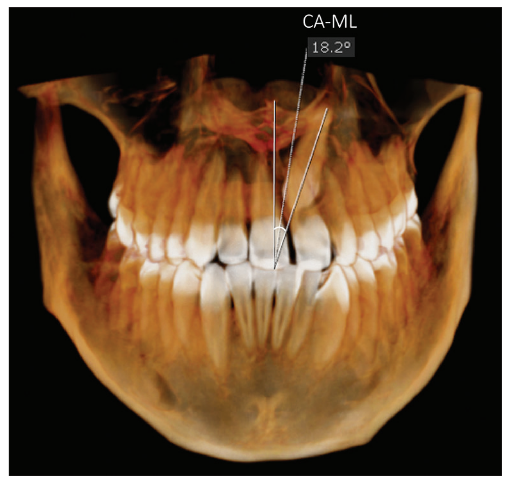

Figure 6: CBCT 3D module used to measure the impacted canine angulation to the midline (CA-ML), an angle formed by the long axis of the maxillary impacted canine and the skeletal midline of the maxilla

correlation. In addition, the study participants were divided into three groups based on the location of the impacted canine (palatal, buccal, and mid-alveolus). Descriptive statistics of the study impacted canine-related variables were calculated to characterize their distributions. Fisher's exact test for categorical variables and Kruskal-Wallis test for continuous variables were used as appropriate to determine any association between the different locations of impacted canine (palatal, buccal, and mid-alveolus) with other impacted canine-related variables; level of significance was declared at α =0.05. Statistical analysis was conducted using SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

For intra-examiner reliability, most of the measurements showed good reliability, with values ranging from 0.83

to 0.99 by ICC, except for the maxillary first premolar alveolar width- axial section (PAWa) of the non-impacted side, where the ICC value was 0.63, which is considered as moderate reliability [Table 1].

Table 2 shows the comparison of maxillary transverse widths on the impacted with the non-impacted one. No statistically significant differences were found in the basal and alveolar widths at the maxillary first molar. Although there was no statistically significant difference detected in the basal width of the maxillary first premolar, the alveolar width of the maxillary first premolar- coronal section (PAWc) was statistically significantly lower ($P < 0.01$) on the impacted side (20.8 ± 1.9 mm) compared with the non-impacted side (21.7 ± 1.4 mm). Similarly, the alveolar width of the maxillary first premolar-axial section (PAWa) was statistically significantly lower ($P < 0.001$) on the impacted side (15.0 ± 1.9 mm) compared with the non-impacted side (16.4 ± 1.2 mm). In addition, the maxillary dental width from the central fossa of the maxillary first molar to the midline (MDW) was statistically significantly lower ($P < 0.03$) on the impacted side (22.3 ± 1.8 mm) compared with the non-impacted side (23.2 ± 1.9 mm). Moreover, the width from the maxillary canine cusp tip to the midline (CCT-ML) ($P < 0.0001$) on the impacted side (9.6 ± 5.0 mm) was statistically significantly narrower compared with the non-impacted (17.0 ± 1.2 mm).

Tables 3 and 4 show the association of maxillary impacted canine location (palatal, buccal, and mid-alveolus) with

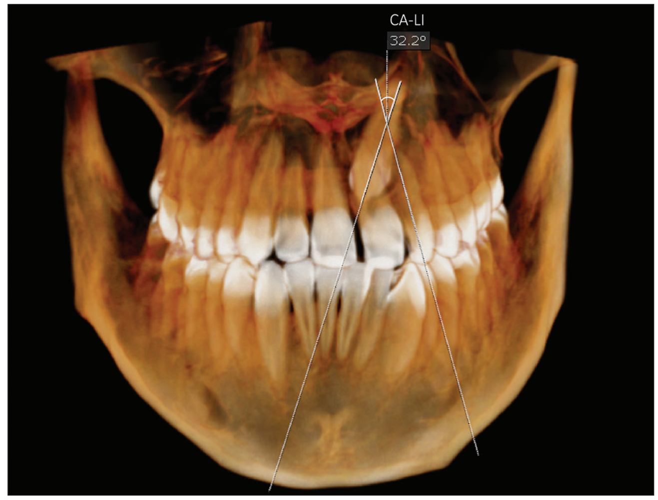

Figure 7: CBCT 3D module used to measure impacted canine angulation to the lateral incisor (CA-LI), an angle formed by the long axis of the maxillary impacted canine and the long axis of the maxillary lateral incisor

Table 1: Intra-examiner reliability

Impacted side	ICC[a]	Non-impacted side	ICC[a]
Maxillary first molar basal width (MBW)	0.84	Maxillary first molar basal width (MBW)	0.93
Maxillary first molar alveolar width (MAW)	0.86	Maxillary first molar alveolar width (MAW)	0.83
Maxillary first premolar basal width (PBW)	0.94	Maxillary first premolar basal width (PBW)	0.93
Maxillary first premolar alveolar width- coronal section (PAWc)	0.95	Maxillary first premolar alveolar width in coronal section (PAWc)	0.89
Maxillary first premolar alveolar width- axial section (PAWa)	0.98	Maxillary first premolar alveolar width in axial section (PAWa)	0.63
Maxillary dental width (MDW)	0.83	Maxillary dental width (MDW)	0.85
Maxillary canine cusp tip to the midline (CCT-ML)	0.99	Maxillary canine cusp tip to the midline (CCT-ML)	0.86
Impacted canine cusp tip to the occlusal plane (CCT-OP)	0.99		
Impacted canine angulation to the midline (CA-ML)	0.99		
Impacted canine angulation to the lateral incisor (CA-LI)	0.99		

[a]ICC: Intraclass correlation coefficient

Table 2: Comparison of maxillary transverse width in millimeters between impacted and non-impacted sides

Variables	Side	Mean	SD	Median	*P*
Maxillary first molar basal width (MBW)	Impacted	30.1	3.2	30.5	0.7[a]
	Non-impacted	30.3	2.4	30.5	
Maxillary first molar alveolar width (MAW)	Impacted	26.6	1.9	27.0	0.1[a]
	Non-impacted	27.2	1.8	27.1	
Maxillary first premolar basal width (PBW)	Impacted side	15.5	3.2	15.2	0.3[a]
	Non-impacted	16.0	2.5	15.8	
Maxillary first premolar alveolar width- coronal section (PAWc)	Impacted side	20.8	1.9	21.0	0.01[a]*
	Non-impacted	21.7	1.4	22.0	
Maxillary first premolar alveolar width- axial section (PAWa)	Impacted side	15.0	1.9	15.6	0.001b*
	Non-impacted	16.4	1.2	16.4	
Maxillary dental width (MDW)	Impacted side	22.3	1.8	22.7	0.04[a]*
	Non-impacted	23.2	1.9	23.2	
Maxillary canine cusp tip to the midline (CCT-ML)	Impacted side	9.6	5.03	10.1	<0.0001[a]*
	Non-impacted	17.0	1.2	17.2	

[a]Paired sample *t*-test. bWilcoxon signed rank test. *Statistically significant ($P<0.05$)

Table 3: Comparison of linear (in millimeters) and angular (in degrees) measurements with the impacted canine location (palatal, buccal, and mid-alveolus)

Variable	Statistic	Palatally (*n*: 8)	Buccally (*n*: 8)	Mid-alveolus (*n*: 6)	*P*[a]
Impacted canine cusp tip to the occlusal plane (CC-OP)	Mean (SD)	7.6 (1.5)	10.8 (3.3)	12.0 (3.9)	0.02*
	Median	7.8	10.3	11.5	
Impacted canine angulation to the midline (CA-ML)	Mean (SD)	24.4 (6.5)	21.6 (12.8)	31.0 (15.4)	0.5
	Median	23.6	20.5	29.5	
Impacted canine angulation to the lateral incisor (CA-LI)	Mean (SD)	44.3 (6.9)	37.7 (10.6)	52.7 (27.1)	0.1
	Median	43.6	37.7	58.3	

[a]Kruskal Wallis test. *Statistically significant (*P*<0.05)

Table 4: Comparison of canine-related variables with the impacted canine location (palatal, buccal, and mid-alveolus)

Variable	Palatal *n* (%)	Buccal *n* (%)	Mid-alveolus *n* (%)	*P*[a]
Type of canine impaction				
Vertical	6 (75%)	5 (62.5%)	3 (50%)	0.9
Horizontal	2 (25%)	3 (37.5%)	3 (50%)	
Deciduous canine				
Presence	4 (50%)	6 (75%)	5 (83.3%)	0.5
Absence	4 (50%)	2 (25%)	1 (16.7%)	
Transposition				
Presence	3 (37.5%)	0	2 (33.3%)	0.2
Absence	5 (62.5%)	8 (100%)	4 (66.7%)	
Root resorption				
Presence	0	1 (12.5%)	0	1.0
Absence	8 (100%)	7 (87.5%)	6 (100%)	

[a]Fisher's exact test

other impacted canine-related variables. Impacted canine angulation to the midline and to the lateral incisor, type of canine impaction (vertical or horizontal), presence of deciduous teeth, presence of transposition, and presence of root resorption were not statistically significantly different when compared with the location of impacted canine (palatal, buccal, and mid-alveolus). However, the distance from the impacted canine cusp tip to the occlusal plane (CCT-OP) was significantly lower ($P < 0.01$) in palatally impacted canine (7.6 ± 1.5 mm) compared to buccally (10.8 ± 3.3 mm) and mid-alveolus (12.0 ± 3.9 mm) impacted canines.

Discussion

The aim of this study was to explore the relationship between unilaterally impacted maxillary canines and maxillary transverse width dimension in the Saudi population by using CBCT. It is crucial to investigate the transverse width dimensions around impacted canines to assess the possible risk factors and complications for maxillary impacted canines and to provide evidence for the importance of early intervention. In this study, all variables were analyzed using both CBCT sections and 3D modules. A pilot study was performed to ensure good reliability of the results. The results of the present study showed no significant difference in the maxillary first molar basal (MBW) and alveolar widths (MAW) between impacted and non-impacted sides. Moreover, no significant difference was found in the basal width of the maxillary first premolar (PBW). Similarly, Hong *et al*.[11] reported similar skeletal maxillary transverse dimensions between palatally impacted canine and control groups based on CBCT images. However, Arboleda-Ariza *et al*.,[14] who evaluated study models, found that groups with unilateral and bilateral impacted maxillary canines showed significantly smaller first molar basal and alveolar widths.

The alveolar width of the maxillary first premolar measured in both coronal (PAWc) and axial sections (PAWa) in the present study was significantly lower ($P < 0.01$) on the impacted side compared with the non-impacted side. These results were consistent with D´ Oleo-Aracena *et al*.,[3] who evaluated the maxillary transverse dimensions of individuals with unilateral palatally impacted canines by using CBCT with a split-mouth design and found statistically significant differences between the impacted and non-impacted side measurements from the mid-palatine raphe to the first premolar; the distance was significantly lower on the impacted side. Furthermore, the results of this study showed that the maxillary dental width (MDW) from the central fossa of the maxillary first molar to the midline was statistically significantly lower ($P < 0.03$) on the impacted side compared with the non-impacted side, whereas Hong *et al*.[11] found no statistically significant differences in maxillary transverse dimension dentally at any level of the maxillary first molar between individuals with palatally impacted canines and controls. Alqerban *et al*.[18] reported a statistically significant reduction in width from the maxillary canine cusp tip to the midline measured axially on the impacted side using CBCT; which is in agreement with the present study, CCT-ML ($P < 0.0001$).

The present results showed no significant association between impacted canine location (palatal, buccal, and mid-alveolus) and the following variables: impacted canine angulation to the midline and to the lateral incisor, the type of canine impaction (vertical or horizontal), the presence of deciduous teeth, transposition, and root resorption. However, the impacted canine cusp tip was statistically significantly closer to the occlusal plane in palatal canine impaction compared to buccal and mid-alveolus canine impaction ($P < 0.01$). On the contrary, Yan *et al*.[16] reported no statistically significant difference in the distance from the impacted canine cusp tip to the occlusal plane between palatally and buccally impacted canines.

It may be beneficial to consider the significant discrepancies detected during orthodontic case evaluation and treatment planning. Nonetheless, future studies using CBCT with a split-mouth design and having a larger sample size with different ethnicities are recommended to further investigate the relationship between canine impaction and maxilla transverse dimension. This study was cross-sectional, and a significant number of CBCT records were excluded to follow the inclusion criteria. Moreover, longitudinal studies may help to evaluate whether the reduction of maxillary width is secondary to the canine impaction or vice versa.

Conclusions

There was a significant association between canine impaction and reduction in the maxillary transverse dimension at least on the dental level in Saudi individuals. In addition, the palatally impacted canine cusp tip was significantly closer to the occlusal plane compared to the buccal and mid-alveolus maxillary canine impaction. These discrepancies may have some clinical implications on orthodontic diagnosis and treatment planning.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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