Sokmen et al. BMC Oral Health (2024) 24:1012
https://doi.org/10.1186/s12903-024-04782-w

BMC Oral Health

RESEARCH

Open Access

Buccolingual inclination of posterior dentition in maxillary impacted canine patients using quadrant analysis - A cone-beam computed tomographic study

Tevhide Sokmen[1*], Nuray Bagcı[2] and Burcu Balos Tuncer[1]

Abstract

Background To examine the buccolingual inclination of maxillary posterior teeth, curve of Wilson, and transversal dimensions in palatally impacted maxillary canine patients, compared to controls by cone-beam computed tomography (CBCT).

Materials and methods Pre-treatment images of 22 bilateral, 32 unilateral impacted maxillary canine patients and 30 controls were included. All patients had palatally impacted canines, with no posterior cross-bite. Data were reclassified in quadrants according to the presence of impaction, as the impaction quadrant (right and left quadrants of 22 bilateral impacted cases, and quadrants presenting impaction of 32 unilateral cases, $n=76$), unaffected quadrant (quadrant without impaction in 32 unilateral cases, $n=32$) and the control quadrant (right and left quadrants of 30 controls, $n=60$) to evaluate the buccolingual inclination angle, transversal width, and arch perimeter. Additionally, comparisons were made regarding curve of Wilson and total arch perimeter among bilateral and unilateral impaction groups with the control group. Statistical analysis was performed by one-way ANOVA and Kruskal Wallis tests. Tukey or Dunn tests were used for comparisons between groups in pairs.

Results No significant difference was found for the buccolingual inclination of maxillary posterior teeth and curve of Wilson among groups. The buccolingual inclination of canines in the impaction quadrant was significantly lower than the other quadrants ($p<0.001$). Basal bone width at the level of second premolars, and alveolar width at both premolars were significantly narrower in the impaction quadrant than in the unaffected quadrant ($p<0.05$). Dental arch width at the level of first premolar was significantly decreased in the impaction quadrant compared to other quadrants ($p<0.05$). Arch perimeter was significantly reduced in the impaction quadrant than in the unaffected quadrant ($p<0.05$).

Conclusion The presence of bilateral or unilateral palatally impacted maxillary canines did not effect the buccolingual inclination of posterior teeth, and curve of Wilson. Transverse discrepancy was evident in the impaction quadrant even in the absence of posterior cross-bite. Quadrant analysis was particularly useful in evaluating

*Correspondence:
Tevhide Sokmen
tevhidesokmen@gazi.edu.tr; tevhide_sokmen@hotmail.com
Full list of author information is available at the end of the article

asymmetry for basal bone and alveolar bone widths in the premolar region in patients with unilateral palatally impacted maxillary canine patients.

Keywords Impacted maxillary canine, Buccolingual inclination, Curve of Wilson, Quadrant analysis, Transversal dimension, Cone-beam computed tomography

Background

Maxillary canines, the most frequently impacted teeth after third molars [1–4], are important in terms of the integrity of the dental arch and aesthetic appearance. Two main theories explain the etiology of palatal impaction of maxillary canines, as the "guidance" and the "genetic" theories. According to the guidance theory, the lack of the guidance of the roots of the maxillary lateral incisors leads to canine impaction. The genetic theory is based on the abnormalities of tooth size, shape, number and/or structures [5, 6]. Their impaction may result in migration of the neighboring teeth, reduced arch length/bone dimensions, or affect angulation of the nearby teeth [7]. Previously, the buccolingual and vertical alveolar bone dimensions and arch perimeter were significantly reduced in the impacted side than the non-impacted side [8]. Split-mouth studies also revealed that the width from the median raphe to the first premolar is lower on the side of impaction than the non-impacted side [9, 10]. Again, Arboleda-Ariza [11] stated that, subjects with unilateral or bilateral impacted maxillary canines have smaller maxillary basal and alveolar transverse dimensions than subjects without impaction.

Maxillary canines provide guidance during mandibular movements depending on their good crown-to-root ratio, and capability of tolerating high occlusal forces [12]. The buccolingual inclination of posterior teeth are also critical for ideal static and functional occlusion, which has been highlighted by Wilson [13]. Okeson [14], further explained that the curve of Wilson ensures effective cuspal contacts, avoiding nonfunctional contacts. Nanda [15] stated that, a flat curve of Wilson between the buccal segments allowed for proper occlusal function, but that "an accentuated curve would result in balancing interferences, especially in the second molar area." In this respect, the buccolingual inclination of teeth has become an interesting topic for orthodontists. Studies stated that buccolingual inclination is influenced by the vertical growth pattern, skeletal sagittal relationship, age, and neighboring teeth loss [16–19]. Once the maxillary canines are impacted, consequences will be generated in the dental arch, which might affect the dentoalveolar development. One of the clinical consequences of this condition is the lack of transverse development of the maxillary arch, especially at the level of premolars [20]. However, literature knowledge is inadequate regarding changes in terms of the inclination of the maxillary posterior dentition and the relating curve of Wilson in maxillary impacted canine cases.

Cone-beam computed tomography (CBCT) provides detailed assessment of the craniofacial tissues by reconstructing scanned structures in multiple planes [21, 22]. They are commonly preferred for the impacted maxillary canine cases [23] to visualize crown and root positions by overcoming the morphological variations [18, 24].

As noted, tooth impaction has an effect on transverse width [11], and tooth inclination is generally due to dentoalveolar compensation for transverse discrepancies. In this sense, it was aimed to examine the dentoalveolar compensation that occurs with buccolingual inclination changes of maxillary posterior teeth, curve of Wilson, and transversal maxillary dimensions in patients with bilateral and unilateral palatally impacted maxillary canines, compared to a control group by using CBCT images. The data were reclassified into quadrants according to the presence of impaction. The hypotheses were (1) the buccolingual inclination angles of maxillary posterior teeth, and curve of Wilson of patients with unilateral or bilateral palatally impacted maxillary canines varies, (2) the skeletal and dental transverse maxillary widths are reduced in palatally impacted maxillary canine patients, when compared to patients with normally erupted canines.

Materials and methods

This retrospective study was approved by the Gazi University Ethical Committee (E-77082166-604.01.02-418431). Sample size (G*Power software Version 3.1.3, Franz Faul, Universität Kiel, Germany) was calculated based on the difference in the arch perimeter variable between the groups [25]. Mean arch perimeter in the bilateral and unilateral impaction groups and the control group were 62.01 mm, 58.31 mm and 60.50 mm respectively, with an effect size of 0.50, when the common standard deviation was 3.04. Accordingly, a level of significance of 0.05 and 90% power with an effect size of f=0,50 analyzed with a one-way ANOVA test required a sample of 18 patients for each group. Therefore, a total of 54 subjects was comprised for the study.

A detailed computer-based search among the CBCT images, taken between January 2014 and December 2022 in the Department of Oral and Maxillofacial Radiology were performed by the same researcher (TS) according to the following inclusion criteria: (1) aged between 14 and 25 years, (2) presence of unilateral or bilateral palatally impacted maxillary canines, (3) no supernumerary/missing/impacted teeth except maxillary canines and third molars, (4) presence of deciduous canines on the impacted side, (5) completed root development of all dentition, (6) crowding less than 5 mm, (7) absence of posterior cross-bite, (8) optimum vertical growth (27°< SNGoGn°<37°), (9) no craniofacial deformities/skeletal asymmetries, (10) no dental crowns or restorations, (11) no history of previous/ongoing orthodontic treatment, and (12) good quality CBCT images. The exclusion criteria were: (1) posterior cross-bite, (2) crowns, caries/extensive restorations, (3) presence of remaining primary dentition, (4) transposed maxillary canines/maxillary odontogenic pathologies, (5) dental/craniofacial deformities/skeletal asymmetries, and (6) history of trauma or surgery. Same criteria were applied to the control group, except the presence of impacted canines. Based on these criteria, CBCT images of 32 patients with unilateral, and 22 patients with bilateral palatally impacted maxillary canine patients were selected from 138 records. The control group was constituted from images of 30 patients out of 79 images, who had been referred to CBCT imaging due to the need of surgical removal of third molars and diagnosed of the mandibular pathologies.

Referencing a previous study [26], a quadrant analysis was used to compare the impacted sides of the dental arches with the normally erupted sides. To this end, the included 84 maxillary arches were divided into right and left quadrants, resulting in 168 quadrants. Further, 3 quadrants were created as the impacted quadrant (right and left quadrants of 22 bilateral impacted cases, and quadrants presenting impaction in 32 unilateral cases, $n=76$), the unaffected quadrant (quadrant with no impaction in 32 unilateral cases, $n=32$), and the control quadrant (right and left quadrants of 30 control cases, $n=60$) (Fig. 1).

Measurements on the CBCT images All images were acquired by the same machine (Promax 3D Mid; Planmeca Oy, Helsinki, Finland), with identical exposure parameters (90 kVp; 12 mA; 0.4 mm voxel size; scan time, 13.2 s, field of view of 20·17 cm and 20·10 cm), in accordance to the radiation protection rules. Three-dimensional images were evaluated using inbuilt software (version 2.7.0; Romexis; Planmeca Oy, Helsinki, Finland). The images were reconstructed in 3 orthogonal planes (sagittal, axial, and coronal views, with 0.4 mm isotropic voxel resolution). To standardize the head position in all images, Frankfurt horizontal plane and the infraorbital plane were parallelized to the floor (Fig. 2). The vertical reference line was constructed by drawing a perpendicular to the horizontal reference passing through the median palatal suture. Intra-observer agreement was assessed with randomly selected CBCT images of 40 patients, and remeasured 15 days after the first measurements. All evaluations were made by the same researcher (TS).

Measurements of the buccolingual inclination The inclination angles were measured for maxillary premolars and molars respectively. The long axis of posterior teeth were determined from the sagittal views according to Masumoto et al. [27], as a line passing from the midpoint of the mesiodistal crown widths through the midpoint at one-third of the root apices (Fig. 3). The long axis determined in the sagittal views were superimposed with the coronal views respectively for each tooth. The long axis of the posterior teeth at the coronal view was determined in reference to a previous study [18], through a line connecting the midpoint of the buccal and palatal cusp tips and the midpoint of the buccolingual width at the cervical base close to the furcation of the anatomic crowns (Fig. 4). The buccolingual inclination of posterior teeth were achieved by measuring the internal angle formed between the long axis of the premolars and molars with the horizontal

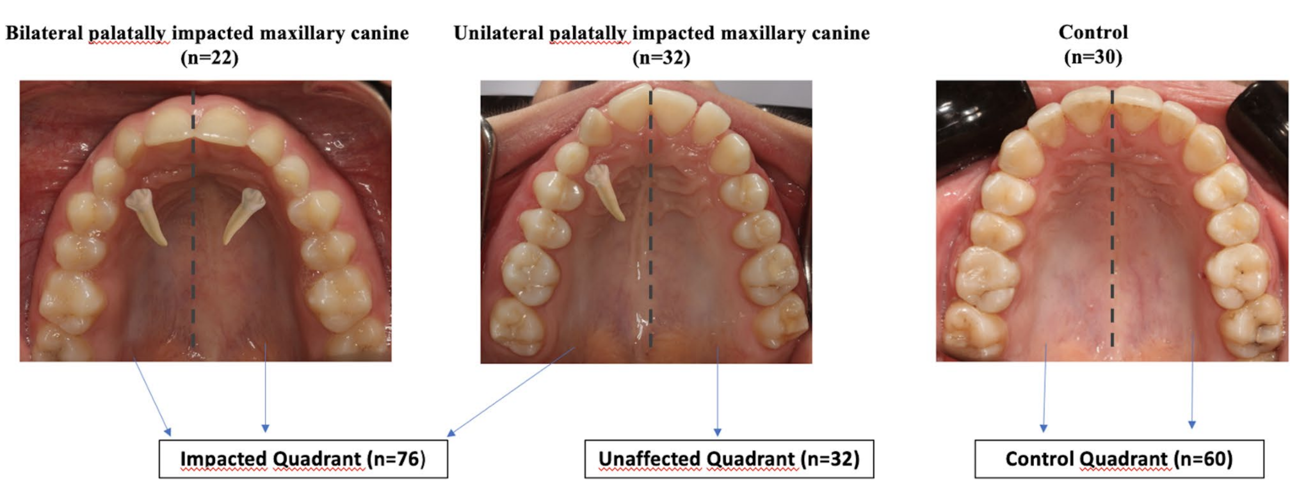

Fig. 1 Recategorization of the bilateral, unilateral palatally impacted maxillary canine and control groups regards to quadrants

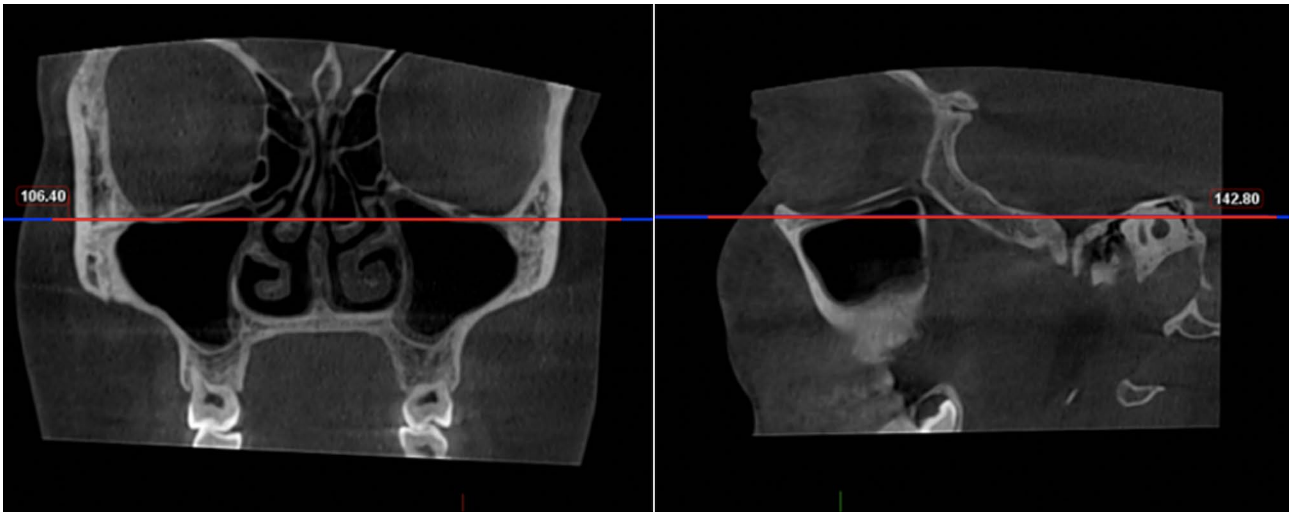

Fig. 2 Frankfurt horizontal plane and infraorbital plane (red lines) were accommodated parallel to the horizontal line (blue line) to standardize the measurements

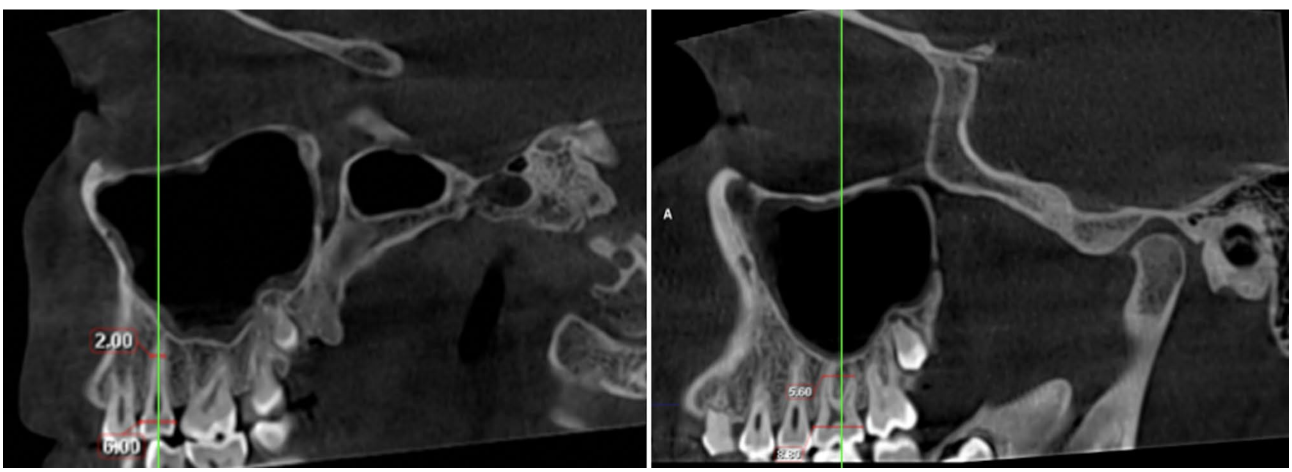

Fig. 3 Determination of the long axis of posterior teeth from the sagittal views, as a line passing from the midpoint of the mesio-distal crown widths through the midpoint at one-third of the root apices

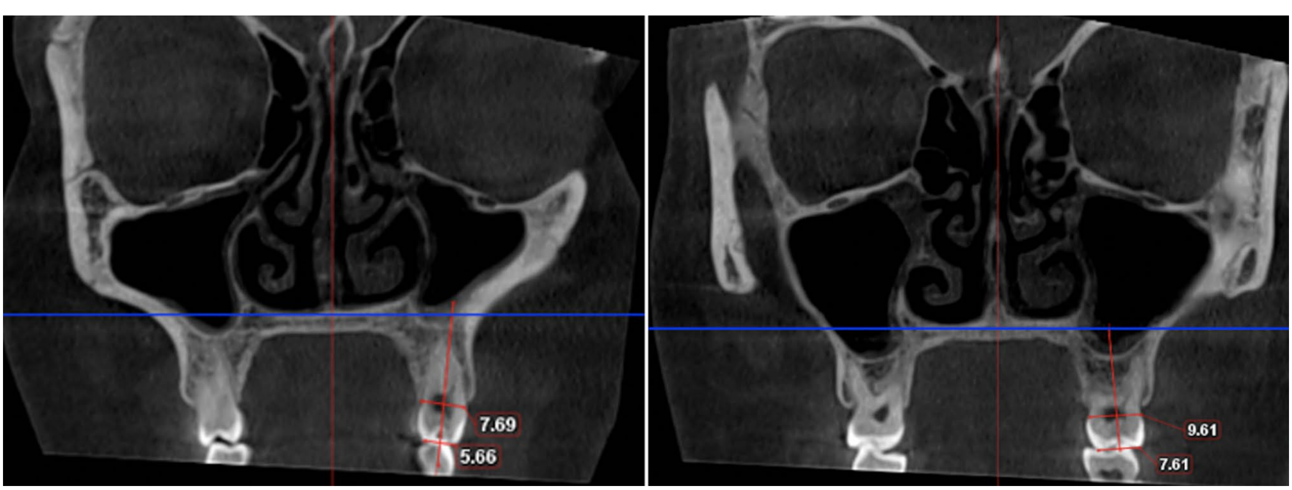

Fig. 4 Determination of the long axis of posterior teeth from the coronal views, through a line connecting the midpoint of the buccal and palatal cusp tips and the midpoint of the bucco-lingual width at the cervical base close to the furcation of the anatomic crowns

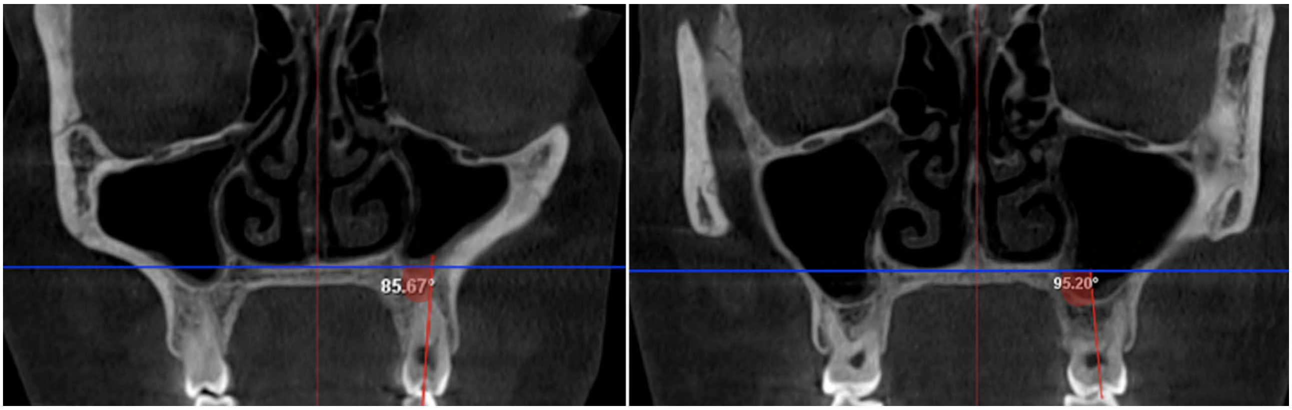

Fig. 5 Bucco-lingual inclination of the premolars and molars. Value of the internal angle of the long axis of the premolars and molars of both quadrants with respect to the horizontal reference plane which parallel to the infraorbital plane on the coronal section

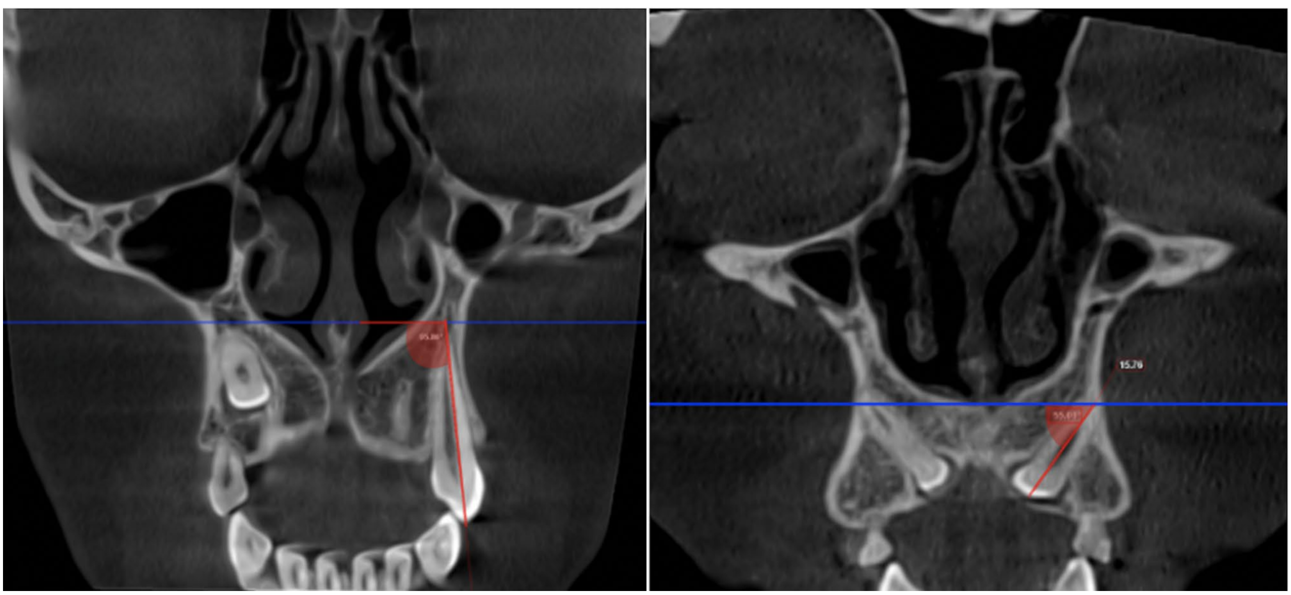

Fig. 6 Buccolingual inclination of the impacted and erupted canines. The angle between impacted and erupted canines long axis and horizontal reference plane on the coronal section

reference plane parallel to the infraorbital plane (Fig. 5). Additionally, the buccolingual inclination angle of the erupted and the impacted maxillary canines were measured on the coronal views. Canine tooth axis was defined as a line that passes through the cusp tip and the apex of the tooth [28]. The angle between the impacted and the erupted canines long axis and horizontal reference plane was measured (Fig. 6).

Measurements of the maxillary transverse dimensions Maxillary transverse widths were measured on the coronal view for right and left first and second premolars and molars separately based on the method of Podesser et al. [29].

The maxillary basal bone width (MBW) was measured from the median palatal suture to the outer edges of the lateral maxillary base along the nasal floor parallel to the horizontal reference plane. The maxillary alveolar width (MAW) was measured between the most coronal points of the maxillary alveolar process and vertical reference plane, parallel to the horizontal reference plane. The maxillary dental width (MDW) was measured between the buccal cusp tip of the tooth and the vertical reference plane, parallel to the horizontal reference plane (Fig. 7).

Measurements of the arch perimeter Arch perimeter for each quadrant was measured on the axial view, from the mesial of the maxillary first molar to the mesial edge of the central incisor for both sides. The total arch perimeter was also measured from the mesial of the right maxillary first molar to the mesial of the left maxillary first molar (Fig. 8).

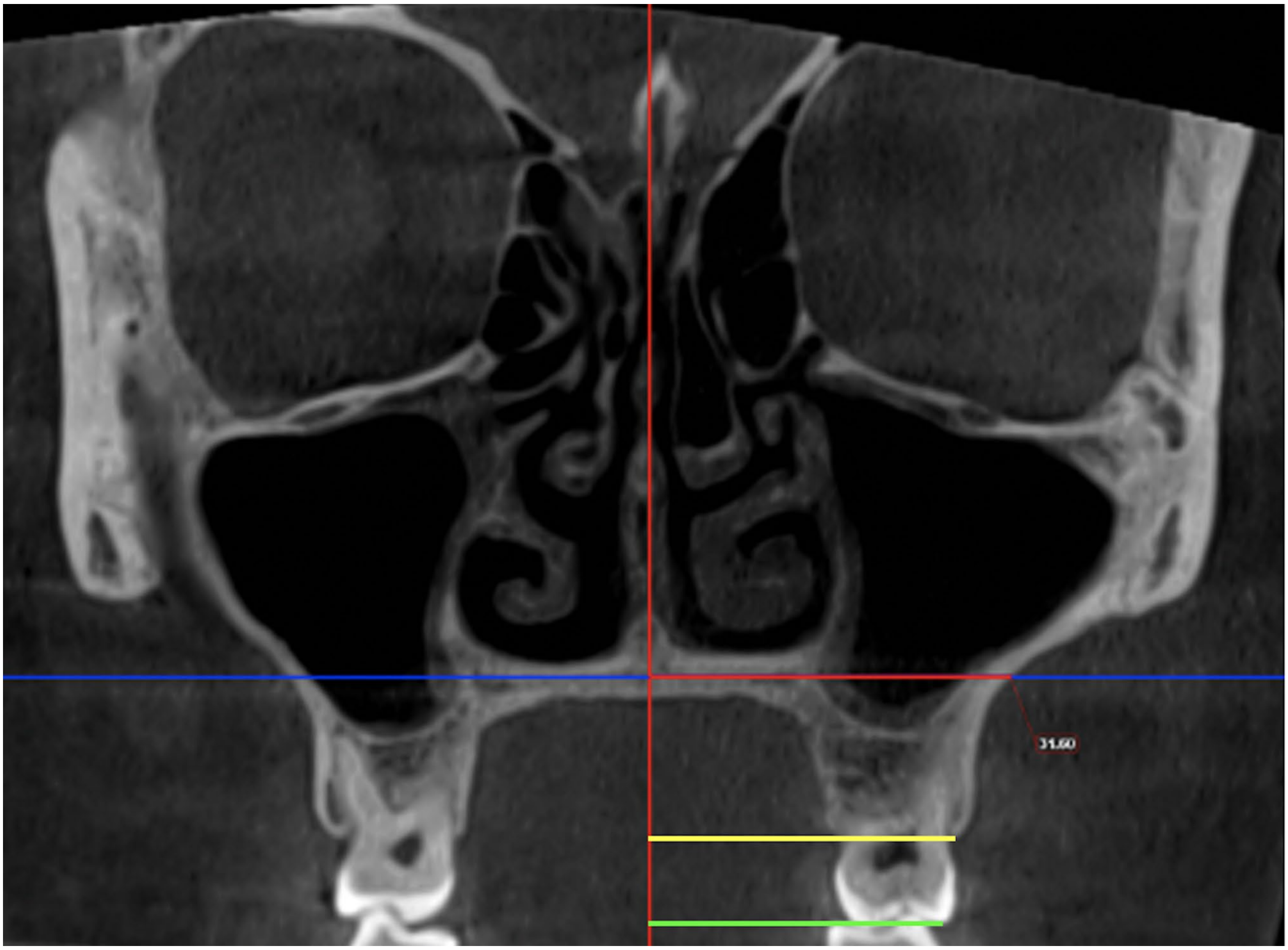

Fig. 7 Maxillary left first molar basal width measurement (red line), alveolar width measurement (yellow line), dental width measurement (green line)

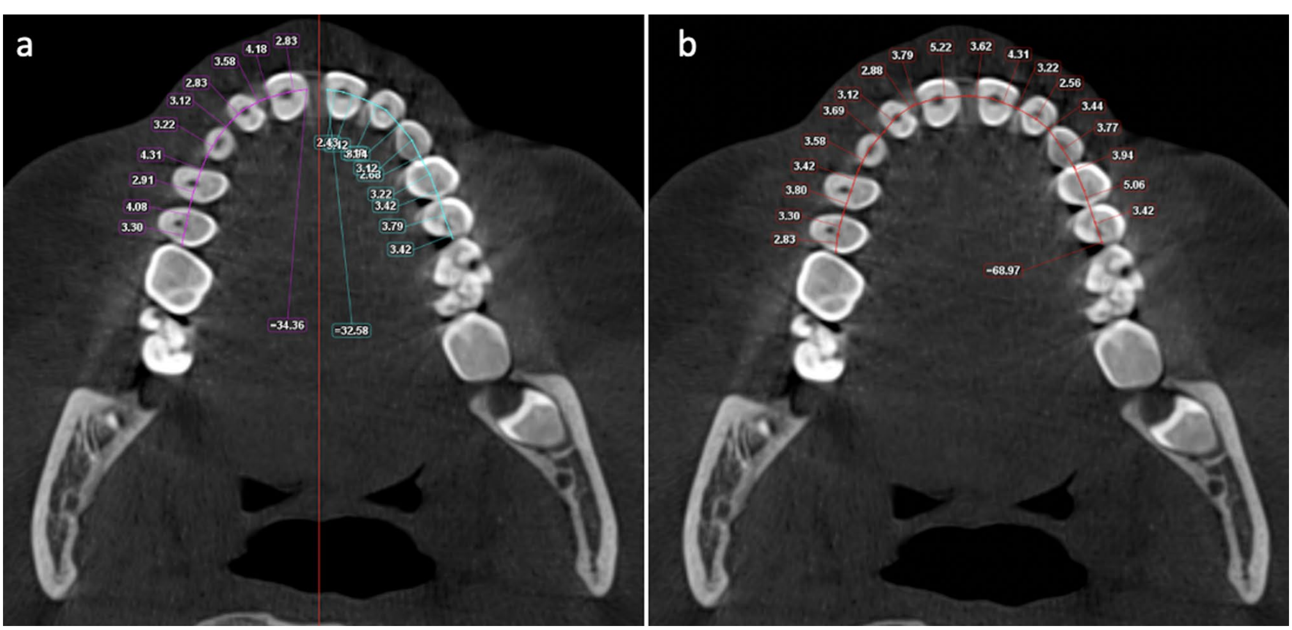

Fig. 8 Arch Perimeter: **a** Quadrant arch perimeter; **b** Total arch perimeter

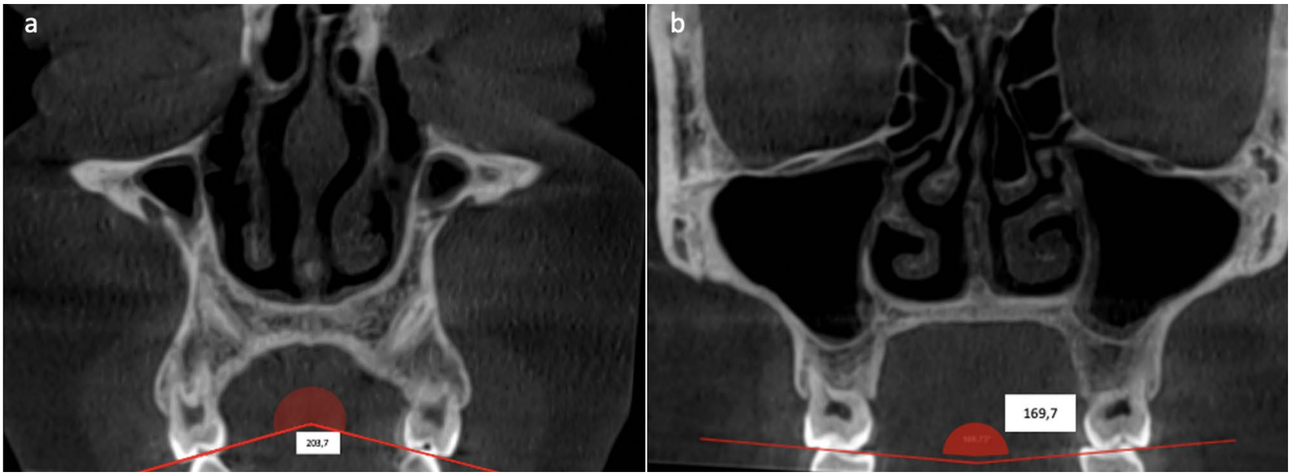

Fig. 9 The curve of Wilson: **a** First premolar curve of Wilson; **b** First molar curve of Wilson. The buccal and palatal cusp tips of the right and left maxillary first premolars as well the mesiobuccal and distopalatal cusp tips of the right and left maxillary first molars were connected along the buccal groove and the palatally formed angle was measured

Table 1 Distributions relative to gender and age, and comparison between groups

Groups	Gender, n (%)			Age		
	Female	Male	P	X ± SD	Median (Min-Max)	P
Bilaterally impacted canine group	17 (28.3)	5 (20.8)	0.155*	20.09 ± 3.89	21.00[a] (14.00–25.00)	0.026[ǂ]
Unilaterally impacted canine group	19 (31.7)	13 (54.2)		17.41 ± 3.41	16.00[b] (14.00–25.00)	
Control group	24 (40.0)	6 (25.0)		18.53 ± 3.28	18.00[a, b] (14.00–25.00)	

X, mean, SD, standart deviation, Min, minimum, Max, maximum. *Pearson chi-square test, ǂKruskal Wallis test; Different superscripted lower-case letters in the same column indicate significant differences between groups (Dunn, $p<0.05$). Same superscripted lower-case letters in the same column indicate non-significant differences between groups (Dunn, $p>0.05$)

Measurements of the curve of Wilson The curve of Wilson was measured on the coronal view at first premolars and first molars, according to Golshah et al. [30]. The buccal and palatal cusp tips of the right and left maxillary first premolars, as well the mesiopalatal and distobuccal cusp tips of the right and left maxillary first molars were connected along the buccal groove and the angles were measured (Fig. 9).

Statistical analysis

The data were analyzed using SPSS (Version 11.5; SPSS Inc, Chicago, Ill) and R programming language. Data were summarized as the mean ± standard deviation and median (minimum-maximum) for continuous variables and frequencies (percentiles) for the categorical variables. The normality of the data was tested by the Shapiro-Wilk test. Categorical variables were compared using the Chi-Square or Fisher's Exact Test as appropriate. The significance of the difference among groups was evaluated by One-way ANOVA or the Kruskal-Wallis test. Pairwise comparisons with the Tukey HSD or Dunn tests were used to assess which groups differed. The intraclass correlation coefficient (ICC) was used for assessment of agreement between test-retest using a two-way mixed model. Statistical significance was set at $p<0.05$.

Results

The ICC values declared excellent intra-examiner reproducibility ($p<0.001$) for all measurements. Twenty-two participants were in the bilateral impacted canine group (26.2%), 32 were in the unilateral impacted canine group (38.1%), and 30 were in the control group (35.7%). The distributions of the groups relative to gender and age are presented in Table 1. There was no significant difference in the distribution of gender, but mean age of the bilateral impacted maxillary canine group was higher than the unilateral group ($p<0.05$).

Comparison of the data regarding the quadrants are given in Table 2. No significant differences were noted for the buccolingual inclination of premolars and molars among the quadrants. Canine inclination angle was significantly reduced in the impaction quadrant (50.93°), when compared to the unaffected quadrant (95.92°), and the control quadrant (95.14°) ($p<0.001$) (Table 2).

Table 2 Comparison of buccolingual inclination, maxillary transverse width and arch perimeter between the quadrant groups

	Impacted quadrant ($n=76$)		Unaffected quadrant ($n=32$)		Control quadrant ($n=60$)		P
	X ± SD	Median (Min-Max)	X ± SD	Median (Min-Max)	X ± SD	Median (Min-Max)	
1st Premolar BLI (°)	90.30 ± 5.66	91.13 (71.20-102.80)	91.54 ± 3.30	91.67 (85.81–98.46)	91.80 ± 4.70	92.19 (78.93-101.69)	0.224[ǂ]
1st Premolar MBW (mm)	18.40 ± 2.40	18.30 (14.00–24.00)	19.22 ± 2.23	19.20 (15.60–25.40)	19.14 ± 2.36	18.80 (14.80–24.40)	0.114*
1st Premolar MAW (mm)	21.69 ± 1.61[A]	21.60 (18.20–26.00)	22.55 ± 1.41[B]	22.50 (19.80–25.80)	22.02 ± 1.34[A, B]	22.00 (18.80–24.80)	0.025*
1st Premolar MDW (mm)	20.48 ± 1.54[a]	20.40 (14.40–23.60)	21.26 ± 1.32[b]	21.20 (19.20–24.40)	21.15 ± 1.49[b]	20.90 (17.60–24.40)	0.017[ǂ]
2nd Premolar BLI (°)	91.14 ± 5.27	90.94 (78.34-104.93)	90.58 ± 4.09	90.44 (81.47-100.44)	92.11 ± 4.73	93.04 (79.80-104.42)	0.305*
2nd Premolar MBW (mm)	25.00 ± 3.68[a]	24.80 (17.20–33.20)	27.26 ± 3.56[b]	28.00 (19.20–35.20)	25.63 ± 3.70[a]	24.80 (17.20–34.00)	0.014[ǂ]
2nd Premolar MAW (mm)	24.40 ± 1.59[A]	24.40 (21.60–28.40)	25.24 ± 1.35[B]	25.10 (22.60–28.40)	24.43 ± 1.51[A]	24.40 (21.60–27.60)	0.023*
2nd Premolar MDW (mm)	23.25 ± 1.59	23.00 (20.00-28.40)	23.83 ± 1.36	24.00 (20.80–27.20)	23.59 ± 1.58	23.50 (20.40–28.00)	0.169*
1st Molar BLI (°)	97.08 ± 4.75	96.78 (84.56-107.24)	98.64 ± 4.61	98.82 (88.36–106.70)	95.99 ± 4.48	96.64 (83.93-103.24)	0.053[ǂ]
1st Molar MBW (mm)	31.63 ± 2.43	31.60 (24.40–39.60)	32.37 ± 2.12	32.20 (29.00-37.20)	32.55 ± 2.81	32.20 (26.80–38.80)	0.147[ǂ]
1st Molar MAW (mm)	27.64 ± 1.58	27.60 (24.40–32.00)	28.13 ± 1.63	28.00 (25.20–33.20)	27.47 ± 1.95	27.20 (19.20–30.80)	0.270[ǂ]
1st Molar MDW (mm)	26.89 ± 1.56	26.80 (23.60–31.60)	27.34 ± 1.65	27.50 (24.80–32.80)	26.71 ± 1.65	26.40 (23.60–30.40)	0.214[ǂ]
2nd Molar BLI (°)	105.19 ± 6.05	104.26 (92.20-122.47)	107.28 ± 4.94	107.90 (95.53-114.34)	104.35 ± 5.54	103.68 (93.37–121.50)	0.063*
2nd Molar MBW (mm)	30.59 ± 2.09	30.60 (25.60–36.00)	31.13 ± 1.96	30.60 (28.00-36.80)	30.85 ± 1.92	30.80 (26.40–35.60)	0.488[ǂ]
2nd Molar MAW (mm)	29.46 ± 2.03	29.30 (24.00-34.80)	29.81 ± 1.94	29.60 (27.20–37.20)	29.16 ± 1.82	29.00 (26.00-33.20)	0.357[ǂ]
2nd Molar MDW (mm)	29.26 ± 1.88	29.10 (23.60–34.40)	29.53 ± 2.05	29.40 (25.80–36.80)	29.24 ± 1.93	28.80 (24.80–34.30)	0.808[ǂ]
Canine BLI (°)	50.93 ± 20.70[a]	51.83 (0.00–90.00)	95.92 ± 6.20[b]	95.67 (85.33-115.39)	95.14 ± 3.92[b]	95.20 (85.07–105.00)	< 0.001[ǂ]
Arch Perimeter (mm)	33.69 ± 2.34[a]	33.63 (27.46–40.12)	35.27 ± 1.78[b]	35.30 (32.16–39.05)	34.57 ± 2.35[a, b]	34.17 (30.33–39.91)	0.002[ǂ]

BLI, buccolingual inclination (°); MBW, maxillary basal width (mm); MAW, maxillary alveolar width (mm); MDW, maxillary dental width; X, mean; SD, standart deviation; Min, minimum; Max: maximum *One-way ANOVA, [ǂ]Kruskal Wallis; Different superscripted upper-case letters in the same row indicate significant differences between groups (Tukey, $p<0.05$). Same superscripted upper-case letters in the same row indicate non-significant differences between groups (Tukey, $p>0.05$). Different superscripted lower-case letters in the same raw indicate significant differences between groups (Dunn, $p<0.05$). Same superscripted lower-case letters in the same raw indicate non-significant differences between groups (Dunn, $p>0.05$)

Maxillary basal bone width and the alveolar width at the level of second premolar was significantly wider in the unaffected quadrant than the impacted and control quadrants ($p<0.05$, respectively). The maxillary alveolar width at the level of first premolar was significantly narrower in the impacted quadrant than the unaffected quadrant. Again, the dental width of the first premolar was significantly narrower in the impacted quadrant compared to the unaffected and control quadrants ($p<0.05$). No significant differences were noted for the first and second molar transverse width measurements ($p>0.05$) (Table 2).

Arch perimeter was reduced in the impacted quadrant than the unaffected quadrant at a significance level of 0.01 (Table 2). Comparison of the curve of Wilson, and total arch perimeter between the groups demonstrated no significant difference (Table 3).

Discussion

Current results revealed that the presence of palatally impacted maxillary canines did not effect the buccolingual inclination of maxillary posterior teeth and curve of Wilson, in comparison with control patients. To our knowledge, no study has examined the compensation of posterior dentition in patients with unilateral and

Table 3 Comparison of curve of Wilson and total arch perimeter between impacted canine, and control groups

	Bilaterally impacted canine group (n = 22)		Unilaterally impacted canine group (n = 32)		Control group (n = 30)		p
	X ± SD	Median (Min-Max)	X ± SD	Median (Min-Max)	X ± SD	Median (Min-Max)	
1st Premolar Wilson (°)	163.19 ± 14.47	168.08 (115.61-179.98)	165.37 ± 7.73	165.84 (147.10-178.96)	166.30 ± 8.91	167.05 (144.90–180.00)	0.827[‡]
1st Molar Wilson (°)	164.12 ± 7.42	164.10 (150.00-178.39)	163.54 ± 8.17	162.60 (149.30-177.23)	164.90 ± 7.19	164.25 (144.30–179.00)	0.782*
Total Arch Perimeter (mm)	67.45 ± 5.00	67.40 (55.90–79.50)	69.34 ± 4.01	69.50 (62.40–78.00)	69.17 ± 4.61	68.55 (61.10–78.60)	0.298[‡]

X, mean; SD, standart deviation; Min, minimum; Max, maximum. * One-way ANOVA, [‡]Kruskal Wallis

bilateral palatally impacted maxillary canines by using quadrant analysis. According to the results, maxillary basal bone width at the level of second premolar, alveolar width at the level of both premolars, and arch perimeter were significantly narrower in the impaction quadrant than in the unaffected quadrant. Maxillary dental width at the level of first premolar was significantly reduced in the impaction quadrant compared both with the unaffected and the control quadrants. Overall, the first hypothesis was rejected, and the second hypothesis was accepted.

Our results are compatible with a CBCT study, which did not find any difference for the maxillary first premolar torque between the impacted and the non-impacted sides in unilateral palatally impacted canine patients [31]. A gradual increase in the inclination of molars from first to third molars has been reported as a feature of human evolution [32, 33]. In agreement with the findings of Yang and Chung [18] and Tong et al. [34], the maxillary molars presented buccal inclination and the inclination angles were increased progressively from the first to the second molars, regardless of the presence of impacted canines in all quadrants. Growth pattern, skeletal sagittal relationship are among the factors that affect buccolingual inclination [16, 17]. Previously, greater buccolingual inclination of maxillary posterior teeth was found in individuals with vertical growth [16], and more lingually inclined maxillary premolars and first molars were noted in Class II division 1 malocclusion than patients with Class I malocclusion [17]. Since the sample size was limited and the study was retrospective, the current data could not be classified in terms of malocclusions or vertical growth pattern, which can be a subject for future studies. Maxillary canines showed less inclination in the impaction quadrant than the unaffected and the control quadrants, in line with the literature [9, 28].

There was no significant difference in the Wilson curve between bilateral and unilateral palatally impacted maxillary canine patients and controls. Golshah et al. [30] found that curve of Wilson at the level of second molars was higher in class II patients than that in class I patients in untreated adults. Mean values for the first molars in class I, class II and class III groups were 167,99 ± 5,40°, 165,81 ± 6,42°, and 165,08 ± 6,08° respectively, with no significant difference. The current values of Wilson curve at the level of maxillary first molars were 164,12 ± 7,42° in bilateral impaction group, 163,54 ± 8,17° in unilateral impaction group, and 164,90 ± 7,19° in the control group, similar to Golshah et al. [30]. Again, a convex pattern in the Wilson curve was found compatible with studies [14, 18].

Arboleda-Ariza et al. [11]. stated that the maxillary first molar basal bone widths were significantly reduced in patients with impacted maxillary canines. In a CBCT assessment, basal bone and alveolar widths of the maxillary first premolars and molars were reduced in the unilateral and bilateral impacted maxillary canine groups than controls [35]. Conversely, Saiar et al. [36], reported no association between skeletal maxillary width and impaction. Another study showed no significant difference in skeletal transverse dimensions at maxillary premolars and first molars between palatally impacted maxillary canines and controls [37]. Similar findings were noted between unilateral palatally impacted maxillary canine and control groups, and also between impacted and non-impacted side subgroups of unilateral palatally impacted maxillary canine group [38]. Saade et al. [39], detected no difference in inter-jugular width between palatally impacted canine group and the control group. In consistence, our results illustrated no significant difference for the basal bone width at the level of premolars and molars between the impacted quadrant and the control quadrant. Discrepancies between results may be attributable to the inclusion criteria or age differences, inclusion of both buccally and palatally impacted maxillary canines, or to the different methods used in the studies. In our study, maxillary basal bone width was significantly narrower at the second premolar level in the impacted quadrant than the unaffected quadrant. One of the reasons for this finding can be explained by the anatomic characteristics of the infrazygomatic crest, which is located between the zygomatic and alveolar process between the maxillary second premolars and first molars in young individuals, and above the maxillary first molar in adults [40]. Great individual variations were observed previously for the infrazygomatic crest anatomy by CBCT images [41]. A study concluded that the thickness of the infrazygomatic crest ranged from 0.9 to 7.4 mm, depending on the root lengths, alveolar processes height, buccolingual inclination of the maxillary first molars, and maxillary sinus pneumatization [42]. The current maxillary alveolar width was narrower in the impaction quadrant than in the unaffected quadrant at the level of both premolars, which might also be due to the presence of an asymmetry in unilateral impaction cases. In our opinion, the clinical relevance of these findings is the presence of a possible transverse asymmetry and dentoalveolar compensation in unilateral impaction cases, which requires further analysis, especially considering assessments in quadrants with larger sample sizes. In line, the asymmetry in transverse width in unilateral maxillary impacted canine cases has previously been explained by the deficiency of transverse development and the lack of stimulation of eruption of the canines on the impacted side [43]. Arriola-Guillén et al. [20], emphasized the association of maxillary canine impaction and narrow maxillary arch, particularly at the premolars, and stated that the treatment induced greater transverse change on the affected side than the unaffected side in unilateral impacted cases, thus resolving the transverse asymmetry. Studies are compatible with these results, in which maxillary alveolar dimensions were significantly reduced in the impacted side compared with the non-impacted side [9, 10, 44]. Yassaei et al. [44], attributed the reduced width of the maxillary dental arch in unilateral cases to the lack of growth and inadequate lateral expansion of the palate on the impacted side. No significant difference was found in this study regarding maxillary alveolar widths between the impaction and the control quadrants, possibly depending on the presence of deciduous canines, and the limited dental crowding. There was an apparent association between intercanine dentoalveolar width and the existence of erupted canines, either deciduous or permanent. When the groups of patients with at least one canine absent (deciduous or permanent) were compared with the groups that had both canines present (deciduous or permanent), the group with the absent teeth showed a significantly smaller intercanine width [36].

Wider maxillary first premolar and molar widths were found in patiens with palatally impacted canines, due to the presence of excess palatal width [45]. Similarly, Saade et al. [39] informed that, maxillary first and second premolars, and first molar widths were significantly wider in unilateral palatally impacted canine cases than controls. However, Sharhan et al. [35] found that, unilateral and bilateral impacted maxillary canine groups had significantly reduced maxillary interpremolar and intermolar widths compared to controls. This is in accordance with our findings, as we found reduced interdental width at first premolar level in the impacted quadrant compared with the other quadrants. In contrast, Hong et al. [37], Naoumova et al. [46] and Shahin et al. [47] reported no difference in maxillary interdental widths in palatally impacted maxillary canine patients. Differences in sample size, ethnicity, age ranges, malocclusions, presence of missing teeth/baby teeth may be the source of differences in results.

Although deciduous canines were present in this study, impacted quadrant revealed reduced arch perimeter, in line with Tadinada et al. [8], who reported decreased arch perimeter on the impacted side in unilateral palatally impacted maxillary canine cases. The authors explained this with the early loss of deciduous canines and mesial migration of the posterior teeth. Peck et al. [48] reported that 16% of palatally impacted canine patients have congenitally missing or peg-shaped lateral incisors, and decreased arch perimeter. In this regard, further studies considering quadrant analysis to evaluate the mesio-distal widths of incisors together with midline discrepancies may be useful in unilateral impacted cases. The total arch perimeter demonstrated no significant difference among bilateral, unilateral impacted groups and the control group, in contrary to studies noting smaller arch perimeter in palatally impacted maxillary canine cases [35, 38, 47]. The discrepancies among studies may be due to the inclusion of buccally impacted maxillary canines in the same study group, the absence of deciduous canines, and the different sample size.

CBCT provided superiority in the ability to visualize the dental structures by avoiding the uncertainties resulting from uneven cuspal wears or irregular tooth morphologies. One of the important limitations of this study is the limited sample size. Again, in unilateral maxillary impacted cases, it would be useful to include tooth dimensions, midline assessments and Angle classifications to interpret the differences between the impacted and the non-impacted sides.

Conclusion

The presence of unilateral and bilateral palatally impacted maxillary canines did not effect the buccolingual inclination of maxillary posterior teeth, and curve of Wilson. Skelatal and alveolar maxillary width were narrower in the premolar area in the impacted quadrant compared to the unaffected quadrant, addressing a possible transverse asymmetry in unilateral maxillary palatally impacted canine cases. In this regard, quadrant analysis may be useful to assess compensation particularly on the unaffected side in unilateral impacted canine patients.

Abbreviations

CBCT	Cone beam computed tomography
BLI	Buccolingual inclination
MBW	Maxillary basal width
MAW	Maxillary alveolar width
MDW	Maxillary dental width

Acknowledgements
Not applicable.

Author contributions
TS performed the data collection and analysis, participated in the study conception, interpreted the results, and wrote the manuscript. NB contributed to methodology and analysis of data. BBT partici-pated in the study conception, supervised the whole project, helped in data analysis, revised the manu-script critically for important intellectual content. All authors read and approved the final manuscript.

Funding
Not applicable.

Data availability
The data used and/or analysed during the current study are available from the corresponding author on reasonable request (tevhidesokmen@gazi.edu.tr). The data are not publicly available due to information that could compromise the privacy of research participants.

Declarations

Ethics approval and consent to participate
This retrospective study was carried out in accordance with the Declaration of Helsinki and was approved by the Ethical Committee of Gazi University with the No. approval E-77082166-604.01.02-41843. Written informed consent form was obtained from all patients before CBCT images are taken for diagnostic examination.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Orthodontics, Faculty of Dentistry, Gazi University, Biskek cad. 1.sokak no:4 Emek, Ankara 06490, Turkey
[2]Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Gazi University, Ankara, Turkey

Received: 29 May 2024 / Accepted: 20 August 2024
Published online: 29 August 2024

References

1. Dachi SF, Howell FV. A survey of 3,874 routine full-mouth radiographs: II. A study of impacted teeth. Oral Surg Oral Med Oral Pathol. 1961;14(10):1165–9.
2. Prskalo K, Zjača K, Škarić-Jurić T, Nikolić I, Anić-Milošević S, Lauc T. The prevalence of lateral incisor hypodontia and canine impaction in Croatian population. Coll Antropol. 2008;32(4):1105–9.
3. Herrera-Atoche JR, Agüayo-de-Pau MdR, Escoffié-Ramírez M, Aguilar-Ayala FJ, Carrillo-Ávila BA, Rejón-Peraza ME. Impacted maxillary canine prevalence and its association with other dental anomalies in a Mexican population. International Journal of Dentistry. 2017;2017.
4. Aktan AM, Kara S, Akgünlü F, Malkoç S. The incidence of canine transmigration and tooth impaction in a Turkish subpopulation. Eur J Orthod. 2010;32(5):575–81.
5. Becker A. In defense of the guidance theory of palatal canine displacement. Angle Orthod. 1995;65(2):95–8.
6. Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. Angle Orthod. 1994;64(4):250–6.
7. Bishara SE, Ortho D. Impacted maxillary canines: a review. Am J Orthod Dentofac Orthop. 1992;101(2):159–71.
8. Tadinada A, Mahdian M, Vishwanath M, Allareddy V, Upadhyay M, Yadav S. Evaluation of alveolar bone dimensions in unilateral palatally impacted canine: a cone-beam computed tomographic analyses. Eur J Orthod. 2015;37(6):596–602.
9. Arriola-Guillén LE, Rodríguez-Cárdenas YA, Ruíz-Mora GA. Skeletal and dentoalveolar bilateral dimensions in unilateral palatally impacted canine using cone beam computed tomography. Prog Orthodont. 2017;18(1):1–7.
10. Prashanth R, Durgekar SG. Evaluation of skeletal and dentoalveolar dimensions in patients with maxillary unilateral impacted canine: a cone beam computed tomographic study. Clin Oral Invest. 2023;27(7):4073–82.
11. Arboleda-Ariza N, Schilling J, Arriola-Guillén LE, Ruíz-Mora GA, Rodríguez-Cárdenas YA, Aliaga-Del Castillo A. Maxillary transverse dimensions in subjects with and without impacted canines: a comparative cone-beam computed tomography study. Am J Orthod Dentofac Orthop. 2018;154(4):495–503.
12. Clark J, Evans R. Functional occlusion: I. A review. J Orthodont. 2001;28(1):76–81.
13. Wilson GH. A manual of dental prosthetics. Lea & Febiger; 1920.
14. Okeson JP. Management of temporomandibular disorders and occlusion-E-book. Elsevier Health Sciences; 2019.
15. Nanda R. Biomechanics and esthetic strategies in clinical orthodontics. Elsevier Health Sciences; 2005.
16. Janson G, Bombonatti R, Cruz KS, Hassunuma CY, Del Santo M Jr. Buccolingual inclinations of posterior teeth in subjects with different facial patterns. Am J Orthod Dentofac Orthop. 2004;125(3):316–22.
17. Shu R, Han X, Wang Y, Xu H, Ai D, Wang L, et al. Comparison of arch width, alveolar width and buccolingual inclination of teeth between class II division 1 malocclusion and class I occlusion. Angle Orthod. 2013;83(2):246–52.
18. Yang B, Chung C-H. Buccolingual inclination of molars in untreated children and adults: a cone beam computed tomography study. Angle Orthod. 2019;89(1):87–92.
19. Beugre-Kouassi AML, Diouf J, Ouattara KS, Beugre J, Aka A. Buccolingual inclination of posterior teeth in untreated adults with unilateral tooth loss: a CBCT Investigation. West Afr J Orthod. 2016;5(2):10–9.
20. Arriola-Guillén LE, Rodríguez-Cárdenas YA, Aliaga-Del Castillo A, Ruíz-Mora GA, Dias-Da Silveira HL. Inter-premolar width changes related to the orthodontic traction of maxillary impacted canines in adolescents and young adults: a retrospective CBCT study. Int Orthod. 2020;18(3):480–9.
21. Mah JK, Huang JC, Choo H. Practical applications of cone-beam computed tomography in orthodontics. J Am Dent Association. 2010;141:S7–13.
22. Agrawal JM, Agrawal MS, Nanjannawar LG, Parushetti AD. CBCT in orthodontics: the wave of future. J Contemp Dent Pract. 2013;14(1):153.
23. Eslami E, Barkhordar H, Abramovitch K, Kim J, Masoud MI. Cone-beam computed tomography vs conventional radiography in visualization of maxillary impacted-canine localization: a systematic review of comparative studies. Am J Orthod Dentofac Orthop. 2017;151(2):248–58.
24. Ross VA, Isaacson RJ, Germane N, Rubenstein LK. Influence of vertical growth pattern on faciolingual inclinations and treatment mechanics. Am J Orthod Dentofac Orthop. 1990;98(5):422–9.
25. Kareem FA, Rasheed TA, Rauf AM, Jalal RA, Faraj BM. Three-dimensional measurements of the Palate and Dental Arch Perimeter as predictors for Maxillary Palatal Canine Impaction—A Cone-Beam Computed Tomography Image Analysis. Diagnostics. 2023;13(10):1808.
26. Bozkaya E, Bavbek NC, Ulasan B. New perspective for evaluation of tooth widths in patients with missing or peg-shaped maxillary lateral incisors: Quadrant analysis. Am J Orthod Dentofac Orthop. 2018;154(6):820–8.
27. Masumoto T, Hayashi I, Kawamura A, Tanaka K, Kasai K. Relationships among facial type, buccolingual molar inclination, and cortical bone thickness of the mandible. Eur J Orthod. 2001;23(1):15–23.
28. Hanke S, Hirschfelder U, Keller T, Hofmann E. 3D CT based rating of unilateral impacted canines. J Cranio-Maxillofacial Surg. 2012;40(8):e268–76.
29. Podesser B, Williams S, Bantleon H-P, Imhof H. Quantitation of transverse maxillary dimensions using computed tomography: a methodological and reproducibility study. Eur J Orthod. 2004;26(2):209–15.
30. Golshah A, Rezaei N, Heshmati S. Buccolingual Inclination of Canine and First and Second Molar Teeth and the Curve of Wilson in Different Sagittal Skeletal

Patterns of Adults Using Cone-Beam Computed Tomography. International journal of dentistry. 2020;2020.
31. Dekel E, Nucci L, Weill T, Flores-Mir C, Becker A, Perillo L, et al. Impaction of maxillary canines and its effect on the position of adjacent teeth and canine development: a cone-beam computed tomography study. Am J Orthod Dentofac Orthop. 2021;159(2):e135–47.
32. Osborn J. Helicoidal plane of dental occlusion. Am J Phys Anthropol. 1982;57(3):273–81.
33. Holly Smith B. Development and evolution of the helicoidal plane of dental occlusion. Am J Phys Anthropol. 1986;69(1):21–35.
34. Tong H, Kwon D, Shi J, Sakai N, Enciso R, Sameshima GT. Mesiodistal Angulation and faciolingual inclination of each whole tooth in 3-dimensional space in patients with near-normal occlusion. Am J Orthod Dentofac Orthop. 2012;141(5):604–17.
35. Sharhan HM, Almashraqi AA, Al-Fakeh H, Alhashimi N, Abdulghani EA, Chen W, et al. Qualitative and quantitative three-dimensional evaluation of maxillary basal and dentoalveolar dimensions in patients with and without maxillary impacted canines. Prog Orthodont. 2022;23(1):1–12.
36. Saiar M, Rebellato J, Sheats RD. Palatal displacement of canines and maxillary skeletal width. Am J Orthod Dentofac Orthop. 2006;129(4):511–9.
37. Hong W-H, Radfar R, Chung C-H. Relationship between the maxillary transverse dimension and palatally displaced canines: a cone-beam computed tomographic study. Angle Orthod. 2015;85(3):440–5.
38. Montes-Díaz ME, Martínez-González A, Arriazu-Navarro R, Alvarado-Lorenzo A, Gallardo-López NE, Ortega-Aranegui R. Skeletal and dental morphological characteristics of the maxillary in patients with impacted canines using cone beam computed tomography: a retrospective clinical study. J Personalized Med. 2022;12(1):96.
39. Saade M, Arai K, Motro M, Saade A, Will LA. Maxillary dimensions and arch shape with palatally displaced canines. Eur J Orthod. 2023;45(3):338–45.
40. Liou EJ, Chen P-H, Wang Y-C, Lin JC-Y. A computed tomographic image study on the thickness of the infrazygomatic crest of the maxilla and its clinical implications for miniscrew insertion. Am J Orthod Dentofac Orthop. 2007;131(3):352–6.
41. Baumgaertel S, Hans MG. Assessment of infrazygomatic bone depth for miniscrew insertion. Clin Oral Implants Res. 2009;20(6):638–42.
42. Santos AR, Castellucci M, Crusoé-Rebello IM, Sobral MC. Assessing bone thickness in the infrazygomatic crest area aiming the orthodontic miniplates positioning: a tomographic study. Dent Press J Orthod. 2017;22:70–6.
43. Fleming PS, Lee RT, Marinho V, Johal A. Comparison of maxillary arch dimensional changes with passive and active self-ligation and conventional brackets in the permanent dentition: a multicenter, randomized controlled trial. Am J Orthod Dentofac Orthop. 2013;144(2):185–93.
44. Yassaei S, Safi Y, Valian F, Mohammadi A. Evaluation of maxillary arch width and palatal volume and depth in patients with maxillary impacted canine by CBCT. Heliyon. 2022;8(10).
45. Al-Nimri K, Gharaibeh T. Space conditions and dental and occlusal features in patients with palatally impacted maxillary canines: an aetiological study. Eur J Orthod. 2005;27(5):461–5.
46. Naoumova J, Alfaro GE, Peck S. Space conditions, palatal vault height, and tooth size in patients with and without palatally displaced canines: a prospective cohort study. Angle Orthod. 2018;88(6):726–32.
47. Shahin SY, Tabassum A, Fairozekhan AT, Tuwaylib AA, Al-Sheyoukh S, Alzaher S et al. The relationship between unilateral Palatal Maxillary Canine Impaction and the morphology of the Maxilla: a CBCT Study in Eastern Province of Saudi Arabia. Eur J Dentistry. 2022.
48. Peck S, Peck L, Kataja M. Site-specificity of tooth agenesis in subjects with maxillarv canine malpositions. Angle Orthod. 1996;66(6):473–6.

Publisher's note