ASSOCIATION BETWEEN MAXILLARY CANINE IMPACTIONS AND PALATAL DIMENSIONS: A CBCT BASED STUDY

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DOI: https://doi.org/10.5281/zenodo.18846995

Keywords
Palatal surface area, impacted canine, intermolar width, interpremolar width, palatal dimensions

Article History
Received: 29 May 2025
Accepted: 13 June 2025
Published: 08 July 2025

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Abstract

Objective: *To investigate the relationship between maxillary canine impactions and palatal dimensions using three-dimensional imagining technique.*

Methods: *After obtaining ethical approval from the Ethical Review Board of Margalla Institute of Health Sciences, Rawalpindi, a comparative cross-sectional study was conducted. It included a total of 134 CBCT scans, comprising 67 patients with palatally impacted maxillary canines (Group 1) and 67 patients with no imapctions in the maxillary arch (Group 2). Intermolar width, interpremolar width and palatal surface area were measured. Axial view on Planmeca Romexis software was used to take linear measurements, whereas palatal surface area was measured after segmentation and export of STL models to 3D Slicer. Data analysis was done using SPSS version 26.0. Independent sample t-test was used to compare groups keeping $p \leq 0.05$ statistically significant.*

Results: *Group 1 comprising impacted canines showed statistically significant reduced palatal dimensions. Mean intermolar width was 46.06 ± 3.05 mm in the impacted group compared to 49.21 ± 2.09 mm in controls ($p < 0.001$). Similarly, interpremolar width was 34.87 ± 1.95 mm versus 37.12 ± 2.01 mm ($p < 0.001$), and palatal surface area was 1502.6 ± 121.5 mm² versus 1639.4 ± 130.8 mm² ($p < 0.001$). Both genders with maxillary canine impactions had decreased palatal surface areas than the control group.*

Conclusion: *Maxillary canine impactions are strongly related with lower intermolar and interpremolar widths, as well as palatal surface area. These findings highlight the significance of early detection and management of transverse disparities in reducing the incidence of impactions.*

INTRODUCTION

Impaction is a disturbance in tooth eruption that has frequently been observed. In orthodontics, it can be defined as the failure of tooth to erupt in its predetermined site, within its normal eruption period due to a physical obstruction or ectopic tooth germ position. For the maxillary canines, it is 14 years of age. If a maxillary canine is positioned in an ectopic position inside the bone before this age, it is called displacement.

Maxillary canine impaction may pose problems to the smile esthetics like asymmetric smiles, dark spaces, midline deviation and gingival discrepencies. The functional significance of canines in disoccluding the posterior teeth during lateral excursions can also not be missed. In addition, maxillary impacted canines have a higher tendency of having short and dilacerated roots.(1) Some other complexities caused by impacted maxillary canine include devitalization and displacement of adjacent teeth, ankylosis, cysts and midline shift.(2)

Maxillary canines are one of the most frequently impacted teeth, second only to third molar impactions, having prevalence ranging from 0.31% to 4.7 depending on ethnic background gender, and presence of alveolar clefts.(3,4) The occurrence of palatally impacted canines is three to six times more than of buccally impacted canines. (5,6)Although, the etiology of maxillary canine impaction in multifactorial, buccally impacted canines are mostly linked with arch length discrepancy whereas palatally impacted canines have genetic factors involved. As maxillary canines have the most torturous route of eruption and is the last tooth to erupt in the maxillary arch it may be caused by the skeletal maxillary structure variation.(7,8,9) Other causes of maxillary impacted canines are disturbances in tooth eruption sequence, trauma, guidance disruptions due to anomalies in adjacent lateral incisors, retention of primary canine, rotation of tooth buds and localized pathological lesions such as cysts and odontomas.

With the recent advancements in the subject of cone-beam computed tomography (CBCT), which allows for a detailed three-dimensional evaluation of craniofacial structures, the precise assessment of palatal dimensions in relation to maxillary canine impactions is now more convenient and accurate than ever.(10,11,12) Studies that make use of CBCTs have shown that decreased palatal depth and length, along with diminished maxillary arch perimeter, may be significant prognostic indicators for palatal canine impaction.(13, 14) Furthermore, an association between decreased alveolar bone dimensions and unilateral palatal impactions on the ipsilateral side has been identified, suggesting localized morphological alterations linked to impaction. (15,16)

Despite these insights, the relationship between palatal dimensions and maxillary canine impactions remains complex. Previously, two dimensional studies have been conducted which could not described the volumetric morphology of the palate.(17,18) Rarely, have there been any studies done using 3D images, especially in Pakistan. This study aims to elucidate the relationship between canine impactions and palatal dimensions by using CBCT images for precise measurements of the palate and dental arch. This can aid in identifying morphological predictors that make individuals susceptible to maxillary canine impactions. Hence, leading to early diagnosis and more effective orthodontic treatment modalities.

MATERIAL AND METHODS

A comparative cross-sectional study was conducted in Margalla Institute of Health Sciences, Rawalpindi after approval from the ethical review committee of the institute. A sample size of 67 participants per group was determined using the WHO calculator through a non-probability consecutive sampling technique.(19) Two groups were made which included male and female patients. The inclusion criteria for group 1 included patients who had dental age 15 years with palatally impacted canines (unilateral or bilateral) having good quality CBCT scans. Group 2 included patients with no impaction in the maxillary arch visible on CBCT scans. Exclusion criteria for both groups was 1) Patients with several impacted teeth or congenitally missing teeth 2) Patients with definitive obstructions (e.g. odontome or supernumerary teeth) 3) Patients with craniofacial anomalies (e.g. cleft lip or palate) 4) Imaging artifacts due to patients' movement 5) Agenesis of maxillary canines 6) Any other pathology in the maxillary arch. New CBCT scans were not done for the sole purpose of conducting this study.

The variables being measured were defined as follows:

- Intermolar width: Distance measured between the central fossae of the right and left first maxillary molars.
- Interpremolar width: Distance measured between the palatal cusp tip of the right and left maxillary first premolars (Fig 1).
- Palatal surface area: Surface area of the palate along the gingival margins of all maxillary teeth up till the distal surface of maxillary first molars.

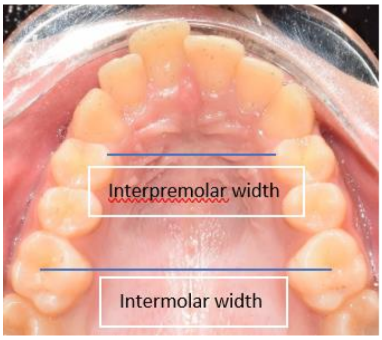

FIG 1. Interpremolar and molar width

Initially, CBCT scans were collected from Islamabad Diagnosticc Centre. Good quality CBCT scans of patients who fulfilled the inclusion criteria were categorized into two groups. All data was anonymized before assessment by the investigator to fulfil the ethical criteria and each CBCT file was allotted a serial number. Planmeca Romexis version 6.0 was used for studying DICOM (Digital Imaging Communication in Medicine) files of the CBCT scans. On Planmeca Romexis, axial views at the occlusal level were used to measure intermolar and interpremolar widths with the measuring tool. For the assessment of palatal surface area, the segmentation tool in Romexis was used to cut out the desired palatal area for assessment. Then STL files of the palate were extracted from Romexis and were measured on 3D Slicer software. After two weeks of assessment, ten CBCT readings were selected randomly and were remeasured to assess the intraclass reliability. Results from each CBCT were coded and analysed using SPSS® statistics version 26.0. Descriptive statistics were calculated for all qualitative and quantitative variables. Qualitative variables like gender were measured in terms of frequency and percentage. Quantitative variables like intermolar width, palatal volume and area were measured in terms of mean and standard deviation. Both groups were compared using independent sample t-test. Effect modifiers like gender were stratified by using post-stratified independent sample t-test. P value less than or equal to 0.05 were considered significant.

RESULTS

A total of 134 patient scans were evaluated. Both groups had 67 participants in each group. Mean age of all participants in both groups was 15.3 ± 0.5 years. There were 62 males (46.3%) and 72 females (53.7%) overall. Gender distribution was similar in both the groups ($p = 0.42$). Out of 134 CBCT scans, only 10 had bilaterally impacted canines due to which comparison between unilateral and bilateral impacted canines was not made.

Group 1 had a considerably reduced mean intermolar width (46.06 ± 3.05 mm) compared to group 2 (49.21 ± 2.09 mm; $p < 0.001$) (Table 1). Similar results were achieved for inter-premolar width, the impacted group had significantly reduced mean which was 34.87 ± 1.95 mm, compared to 37.12 ± 2.01 mm in the control group ($p < 0.001$).

When comparing the palatal surface area for both the groups, significant reduction in surface area of the canine impaction group (mean 1502.6 ± 121.5 mm^2) was observed compared to the control group (1639.4 ± 130.8 mm^2; $p < 0.001$).

Table 1 Results comparing intermolar width, interpremolar width and palatal surface area of canine impaction group with control group. P value less than 0.05 was considered significant.

Parameter	Impacted Canine Group (n=67)	Control Group (n=67)	p-value
Intermolar width (mm)	46.06 ± 3.05	49.21 ± 2.09	<0.001
Interpremolar width (mm)	34.87 ± 1.95	37.12 ± 2.01	<0.001
Palatal surface area (mm²)	1502.6 ± 121.5	1639.4 ± 130.8	<0.001

Gender stratification showed that females and males in group 1 showed narrower arches and constricted palatal surface areas compared to their respective control counterparts, however the intergroup differences were more pronounced in females (Table 2).

Table 2 Gender wise palatal surface area. P-value of less than 0.05 was considered significant

Gender	Impacted Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Male (n=64)	1520.8 ± 118.2	1648.3 ± 126.7	0.002
Female (n=70)	1488.4 ± 125.0	1631.2 ± 133.4	<0.001

DISCUSSION

This CBCT-based study investigated the association between maxillary canine impactions and the dimensions of the palate, including intermolar width, interpremolar width, and palatal surface area. The results demonstrated that patients with palatally impacted maxillary canines, unilateral or bilateral, exhibited significantly narrower maxillary arches and smaller palatal surface areas than individuals without canine impactions.

The findings agree with previous studies that have highlighted a correlation between arch constriction and canine impaction. Several authors have proposed that inadequate transverse maxillary growth and reduced available arch space predispose canines to ectopic eruption or impaction. Our results strengthen this hypothesis by providing quantitative 3D evidence using CBCT and validated measurement software.

Previouis studies (20,21,22), have results similar to our study which noted reduction in intermolar and interpremolar widths in the impaction group and maxillary transverse deficiency as a common feature in patients presenting with impacted canines. Similarly, the smaller palatal surface area in the impaction group is comparable to the conclusions drawn by Salim et al., who found that patients with palatally displaced canines often present with narrow, high-arched palates.

A novel aspect of this study is the measurement of palatal surface area using CBCT-derived 3D models. While previous studies have largely focused on linear dimensions such as intermolar or interpremolar widths, our study highlights the utility of surface area as a more comprehensive indicator of palatal morphology. This method accounts not only for the transverse dimensions but also the curvature of the palatal vault.

The prevalence of narrower arches and smaller palate surface areas in patients with canine impactions emphasizes the significance of early orthodontic evaluation and treatment. Maxillary expansion procedures may be used as a preventive or corrective measure to enhance the available space for canine eruption. Furthermore, quantifying palatal surface area may benefit in treatment planning by providing a 3D picture of the available intraoral space.

The findings of this study also suggest that CBCT imaging can be an invaluable diagnostic adjunct in complex orthodontic cases. By allowing accurate visualization of the skeletal and dental structures in three dimensions, CBCT enables clinicians to make precise measurements and tailor treatment plans accordingly.

Our subgroup analysis revealed that while both males and females with impacted canines showed reduced palatal dimensions compared to their counterparts, the differences were slightly more pronounced among females. This could be attributed to the generally smaller craniofacial dimensions in females, making them more susceptible to spatial limitations. However, the gender differences did not alter the overall trend of the results.

One of the strengths of this study is the use of Planmeca Romexis and 3D Slicer software for measurement. Romexis was employed for linear measurements on axial views, while STL models were exported to 3D Slicer for accurate computation of palatal surface areas. This combination of tools provided a reliable and reproducible workflow for both 2D and 3D assessments. Additionally, intraclass correlation analysis demonstrated excellent intra-examiner reliability, indicating that the measurement methodology used in this study was robust.

Despite its strengths, this study has certain limitations. The cross-sectional design rules out any causal relationship between lower palatal dimensions and canine impactions. It is uncertain if a narrow palate causes canine impaction or if both are impacted by a single etiological source, such as genes. Furthermore, the investigation was conducted at a single institution. This may introduce selection bias. The sample size, while acceptable for statistical analysis, may not be representative of the overall population of Pakistan.

Another limitation relates to the segmentation process. Although STL-based surface area measurement is more comprehensive than linear measurement, the selection of the palatal region for segmentation may involve a degree of subjectivity. Future studies could explore automated segmentation techniques to reduce operator-dependent variability.

Future research should focus on longitudinal investigations to see if early detection of reduced palate dimensions can predict canine impactions. Interventional trials investigating whether maxillary expansion can prevent impaction in at-risk patients would also be beneficial.

CONCLUSION

When compared to control group, patients with impacted maxillary canines have noticeably smaller palate surface areas and narrower maxillary arches. In order to potentially reduce the risk of impactions, these findings emphasize the significance of early diagnosis and treatment of transverse discrepancies.

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