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RESEARCH ARTICLE

COMPARISON OF MAXILLARY DENTOALVEOLAR DIMENSIONS IN PATIENTS WITH VERTICAL AND HORIZONTAL GROWTH PATTERN IN MAXILLARY CANINE IMPACTION

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ABSTRACT

Maxillary canine impaction, affecting 1–3% of the population, poses both functional and esthetic challenges in orthodontics. Skeletal growth patterns and dentoalveolar dimensions are critical factors influencing its occurrence. This study aimed to evaluate and compare maxillary dentoalveolar characteristics in patients with vertical and horizontal growth patterns using Cone-Beam Computed Tomography (CBCT). A retrospective cross-sectional analysis was performed on CBCT scans of 30 patients, equally divided into vertical and horizontal growth types, classified using Steiner's SN-GoGn angle. Measurements included inter-canine width (ICW), inter-molar width (IMW), arch length (AL), and arch perimeter (AP). Results revealed that patients with vertical growth patterns had significantly narrower transverse dimensions (ICW: 26.79 ± 3.89 mm; IMW: 48.61 ± 1.88 mm) compared to those with horizontal patterns (ICW: 31.34 ± 1.43 mm; IMW: 55.49 ± 2.59 mm; $p < 0.001$). Arch length was greater in the vertical group (26.44 ± 1.59 mm) than in the horizontal group (23.90 ± 1.31 mm), with no significant difference in arch perimeter. Basal measurements also showed notable variation ($p \leq 0.03$). These findings suggest that vertical growth patterns are linked with constricted maxillary arches, increasing the risk of canine impaction. Early identification via CBCT and timely interceptive measures, such as dentoalveolar expansion, are advisable for effective management.

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INTRODUCTION

Impacted maxillary canines are most commonly seen in orthodontic practice. Abnormalities involving canines—such as ectopic eruption, transmigration, transposition, agenesis, and impaction—generally result from disturbances in tooth development and eruption.Canines are the longest teeth in the dentition and serve an essential function in directing adjacent teeth into their proper intercuspal alignment. When treating patients holistically, it's crucial to take into account the position and form of the canines. A tooth that does not erupt despite full root development or when the opposing tooth has erupted for at least six months with its root fully formed is said to have an impaction, according to Lindauer et al.(1).This eruption anomaly may be associated with morphological variations in the dentoalveolar and maxillofacial structures (2). The etiology of impacted canines is primarily explained by two main theories: the genetic theory proposed by Becker (3) and the guidance theory suggested by Sacerdoti and Baccetti(4).Peck et al. suggested that the cause extends beyond just genetically linked defects, highlighting the higher occurrence of bilateral cases, significant gender disparities, and the clustering of symptoms within affected families as contributing factors.(5) (6). It remains uncertain whether a malformed lateral incisor directly contributes to palatal displacement of canines, as suggested by the guidance theory, or if the displacement is due to underlying genetic developmental factors, as proposed by the genetic theory. The relationship between maxillary morphology, particularly the maxillary transverse dimension, and impacted maxillary canines is controversial and sometimes contradictory(7). McConnell et al. associated a lack of width in the upper jaw with canine teeth displaced towards the palate(8). Finding out if the proportions of the dentoalveolar and maxillary transverse skeletal structures are connected to impacted maxillary canines becomes significant. It is advised to perform studies of this kind on patients who are adults because the changes in the jaw dimensions that may arise from the craniofacial growth and development throughout adolescence(9). A substantial reduction in alveolar bone dimensions on the impaction-affected side has been documented by a number of researcher (10,11). Other researchers have reported a significant decrease in the alveolar bone's size on the affected side.This suggests that narrower maxillary width measurements might lead to a greater likelihood of teeth becoming impacted because there is insufficient room in dental arch (12). Studies have shown that individuals with a horizontal growth pattern are three times more likely to experience canine impaction compared to those with normal growth, indicating a connection between vertical craniofacial traits and the occurrence of impaction.(4). Patients with impacted maxillary canines were found to have a wider maxilla in the transverse dimension but reduced dimensions in the sagittal and vertical planes, highlighting the importance of a three-dimensional assessment of space in cases involving ectopic canines(13).Changes in the jaw's size may be caused by the adolescent stage of craniofacial growth and development(9). Compared to conventional CT, CBCT offers superior image clarity, lesser radiation exposure, and lower costs, making it the most accurate diagnostic method for finding impacted teeth. Additionally, it removes problems that are frequently seen in panoramic radiography, like superimposition, image blurring, and the overlap of nearby anatomical structures.Therefore, the purpose of this study is to use CBCT to compare the dentoalveolar dimensions in vertical and horizontal growth patterns in patients with maxillary canine impaction.

Identification of Research gaps: It is debatable and occasionally contradictory how impacted maxillary canines and maxillary morphology, including the maxillary transverse dimension, are related. A transverse maxillary deficiency and misplaced canines were related, according to McConnell (8). To date, no study has yet compressively evaluated the dentoalveolar measurements of the impacted maxillary canines in patients with horizontal and vertical growth pattern hence this study aimed to three dimensionally evaluate the dentoalveolar dimensions in patients with maxillary impacted canines

MATERIALS AND METHODOLOGY

This study is a retrospective, cross-sectional analysis aimed at evaluating specific dentofacial parameters using Cone-Beam Computed Tomography (CBCT) images. Archived radiographic records will be utilized to assess pre-treatment anatomical characteristics in selected patients.The data for this research will be obtained from the archives of CBCT images stored in the Department of Oral Medicine and Radiology. These records, collected prior to any treatment, belong to patients of the Faculty of Dental Sciences at Ramaiah University. The study will span a period of 18 months. The study uses CBCT images obtained with carestream CS9300 Premium device, with field of views ranging from 10x5cm to 17x13.5cm. The images are reconstructed and measured on a 21.3-in. flat-panel color active-matrix thin-film transistor medical display. The images are exported in DICOM file format and entered intocarestream CS9300 Premium imaging software. The volume is calculated using multiplanar reconstruction pictures and manual segmentation. To determine the appropriate sample size, GPower software (version 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Germany) was used. With a 5% alpha error ($\alpha = 0.05$), an effect size of 1.35 as reported by Hasan M. Sharhan et al. in 2022, and a study power of 80% at a 95% confidence interval, it was found that a minimum of 30 samples would be required. These will be divided into two groups, with 15 subjects each representing vertical and horizontal growth patterns. Participants will be selected based on specific inclusion criteria. Eligible individuals must be between 12 and 30 years of age, possess one or both impacted maxillary canines, and have a full set of erupted teeth, with or without third molars. Those with a horizontal growth pattern, defined by a mandibular plane to FH angle of less than 17 degrees, or a vertical growth pattern, defined by a mandibular plane to FH angle greater than 28 degrees, will be included regardless of malocclusion type. Only CBCT scans with clear and high-definition images will be considered for analysis.Patients will be excluded if they have undergone prior orthodontic treatment, present with missing teeth due to agenesis, or have maxillary lesions, trauma, or tumors. Additional exclusion criteria include aggressive or advancing periodontitis, cleft lip or palate, craniofacial deformities, hyperdontia or hypodontia, disorders affecting the head and neck region, and systemic bone diseases.Three-dimensional CBCT images will be utilized for data collection. Several cross-sectional views will be acquired from these scans to carry out the necessary analysis for the study.

The primary objective of this study was to assess the dentoalveolar dimensions in patients with maxillary canine impaction and vertical growth pattern and horizontal grown pattern are determined using lateral cephalogram. This includes comparisons of inter-canine width (ICW), inter-molar width (IMW), arch length (AL), arch perimeter (AP), Arch Depth(AD), and other basal dimensions like premolar and molar basal widths. The detailed dentoalveolar measurements are summarized in Table 4.1.And the quantitative basal and dentoalveolar measurements are illustrated in Fig 4.1 and Fig 4.2, respectively. In this study, vertical and horizontal growth patterns were determined using lateral cephalograms by measuring Steiner's SN-GoGn angle, which is formed between the anterior cranial base (Sella-Nasion, SN) and the mandibular plane (Gonion-Gnathion, Go-Gn). A reference mean value of 32° was used for classification: an SN-GoGn angle greater than 32° indicated a vertical (dolichofacial) growth pattern, typically associated with increased lower facial height and a tendency toward skeletal open bite, while an angle less than 32° indicated a horizontal (brachyfacial) growth pattern, associated with reduced lower facial height and a propensity for deep bite. These cephalometric measurements enabled accurate categorization of subjects into distinct growth patterns, facilitating clinically relevant comparative analysis for orthodontic diagnosis and treatment planning (15).

To assess the association between dentoalveolar dimensions in patients with maxillary canine impaction exhibiting vertical and horizontal growth patterns, a retrospective study was undertaken. The alveolar bone width was measured in individuals grouped according to their growth patterns. Archived patient records and CBCT images were used as the data source. Two independent examiners initially categorized the samples into horizontal and vertical growth pattern groups based on cephalometric analysis. These categorized data sets were then forwarded to the principal investigator, who remained blinded to the group assignments throughout the measurement phase to minimize potential bias. The principal investigator proceeded to evaluate dentoalveolar dimensions, using CBCT images. After these measurements were obtained, the data was re-submitted to the same independent examiners, who reassigned the measurements into their respective horizontal and vertical growth categories. Following this segregation, the collected data was subjected to statistical analysis to evaluate the association between dentoalveolar dimensions and the identified growth patterns. This methodology ensured objectivity, reproducibility, and the reliability of findings related to the differences in dentoalveolar measurements between vertical and horizontal growers.

STATISTICAL ANALYSIS

Statistical analysis for the study will be conducted using the Statistical Package for Social Sciences (SPSS) for Windows, Version 22.0 (Released 2013, IBM Corp., Armonk, NY). Descriptive statistics will be used to express quantitative basal and dentoalveolar measurements as mean and standard deviation (SD) for each group. For inferential analysis, the Independent Student t-test will be applied to compare the mean values of these measurements between vertical and horizontal growth pattern groups. A significance level of $p < 0.05$ will be considered to determine statistical significance.

RESULTS

The comparison between vertical and horizontal growth patterns showed statistically significant differences in multiple maxillary dentoalveolar and basal parameters. A detailed summary of these measurements is presented in Table 5.1 and Table 5.2. The comparison of quantitative basal measurements between vertical and horizontal growth patterns demonstrated significant differences across parameters. Molar basal width was lower in the vertical growth pattern, with a mean of 58.033 ± 3.076, compared to 61.140 ± 2.599 in the horizontal growth pattern. The difference of -3.107 was statistically significant (p=0.006).

Table 4.1. Dentoalveolar Measurements

Measurement	Abbreviation	Definition
Molar Arch Width	MAW	Measured on the first molar coronal slice between the most occlusal sites of the maxillary alveolar process.
Premolar Arch Width	PMAW	Measured on the first premolar coronal slice between the most occlusal sites of the maxillary alveolar process.
Inter-Molar Width	IMW	Distance between the right and left mesiobuccal cusps at the center of the maxillary first molars.
Inter-Premolar Width	IPW	Distance between a set position in the right and left buccal cusps at the center of the maxillary first premolars.
Inter-Canine Width	ICW	Measured between the right and left center of the maxillary canines.
Arch Perimeter	AP	Measured from the mesiobuccal cusp of the first permanent molar on one side to the same cusp on the opposite side along the arch.
Arch Length	AL	Distance from the mesial contact point of the incisors to the inter-molar plane, taken perpendicular to the midline.
Molar Basal Width	MBW	Measured at the nasal floor reference plane along the line joining the outer corners of the right and left sides of the maxillary base (lateral limits).
Premolar Basal Width	PMBW	Measured at the nasal floor reference plane along a line joining the outer edges of the right and left maxillary base at the premolar region (lateral limits).
Arch Depth	AD	Distance from the mid-palatal point to the inter-molar line connecting the buccal cusps of the right and left first maxillary molars.

Note: All measurements were obtained using **secondary reconstruction mode** via cross-sectional CBCT views, with orientation coordinates used to align the jaw bone parallel to a reference surface (14).

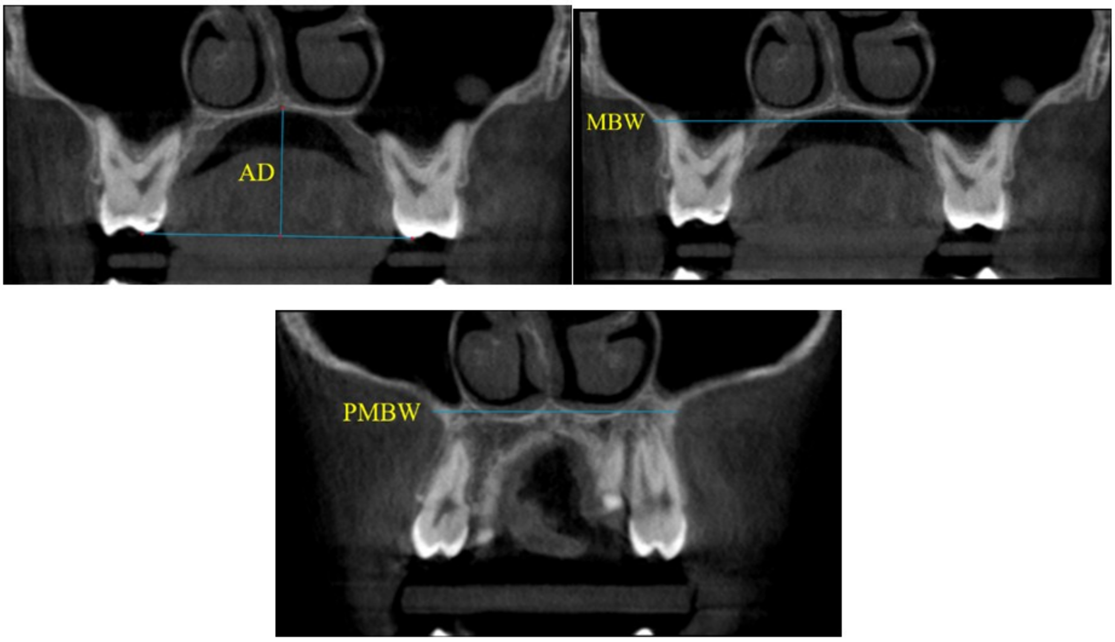

Fig 4.1. The quantitative basal measurements: a) AD, arch depth; b) MBW, first molar basal width; and c) PMBW, first premolar basal width

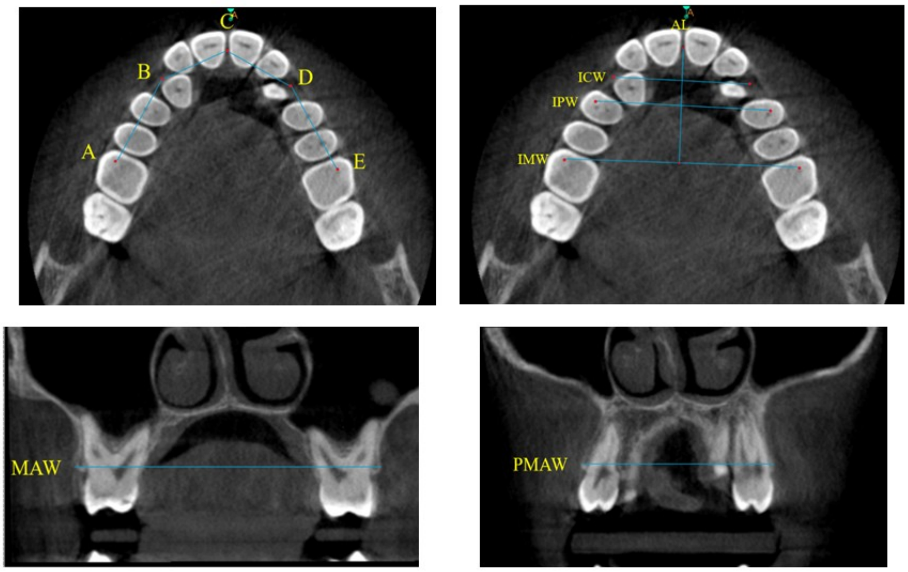

Fig 4.2. The quantitative dentoalveolar measurements: a) Arch perimeter: the sum of distances A–B, B–C, C–D, and D–E;b) IMW, inter-molar width; IPMW, inter-premolar width; ICW, inter-canine width; and AL, arch length; c) MAW, first molar alveolar width; d) PMAW, first premolar alveolar width

Table 5.1. Comparison of mean values of Quantitative basal measurements between Vertical and Horizontal Growth Pattern using Independent Student t Test

Parameters	Groups	N	Mean	SD	Mean Diff	p-value
Molar Basal Width	Vertical	15	58.033	3.076	-3.107	0.006*
	Horizontal	15	61.140	2.599		
Premolar Basal Width	Vertical	15	38.540	3.126	-2.307	0.03*
	Horizontal	15	40.847	2.243		
Arch Depth	Vertical	15	19.293	1.601	1.426	0.02*
	Horizontal	15	17.867	1.594		

Table 5.2. Comparison of mean values of Quantitative dentoalveolar measurements between Vertical and Horizontal Growth Pattern using Independent Student t Test

Parameters	Groups	N	Mean	SD	Mean Diff	p-value
Molar Arch Width	Vertical	15	57.353	3.192	0.406	0.71
	Horizontal	15	56.947	2.723		
Premolar Arch Width	Vertical	15	44.720	3.025	0.307	0.75
	Horizontal	15	44.413	2.211		
Inter-Molar Width	Vertical	15	48.607	1.881	-6.886	<0.001*
	Horizontal	15	55.493	2.588		
Inter-Premolar Width	Vertical	15	37.200	1.380	-1.847	0.002*
	Horizontal	15	39.047	1.584		
Inter-Canine Width	Vertical	15	26.787	3.890	-4.553	<0.001*
	Horizontal	15	31.340	1.429		
Arch Length	Vertical	15	26.440	1.586	2.540	<0.001*
	Horizontal	15	23.900	1.310		
Arch Perimeter	Vertical	15	76.307	2.961	0.580	0.53
	Horizontal	15	75.727	1.939		

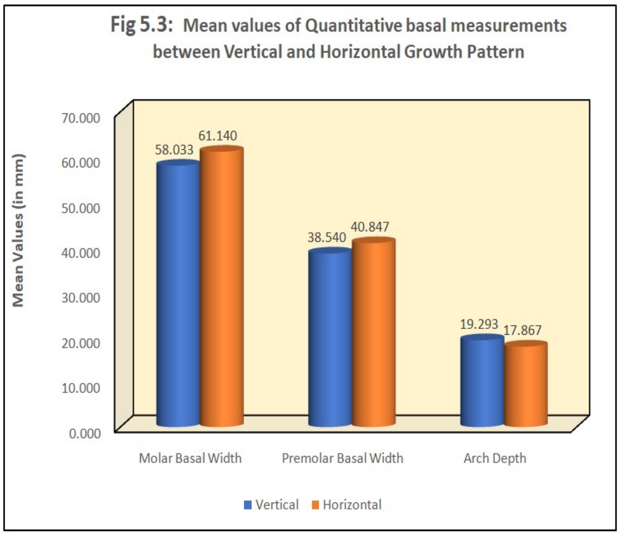

Fig 5.3: Mean values of Quantitative basal measurements between Vertical and Horizontal Growth Pattern

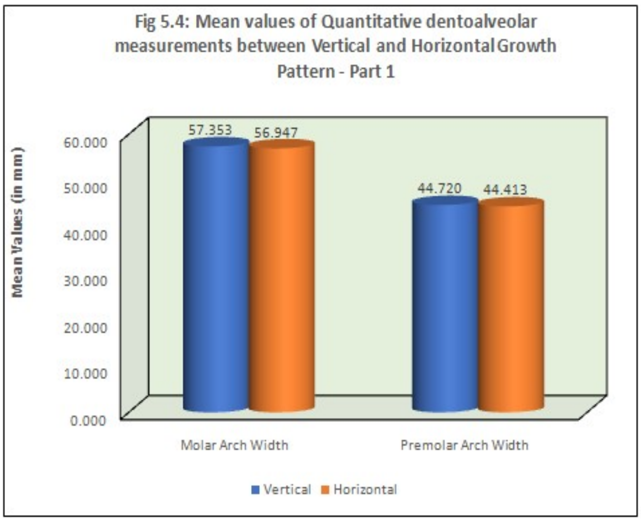

Fig 5.4: Mean values of Quantitative dentoalveolar measurements between Vertical and Horizontal Growth Pattern - Part 1

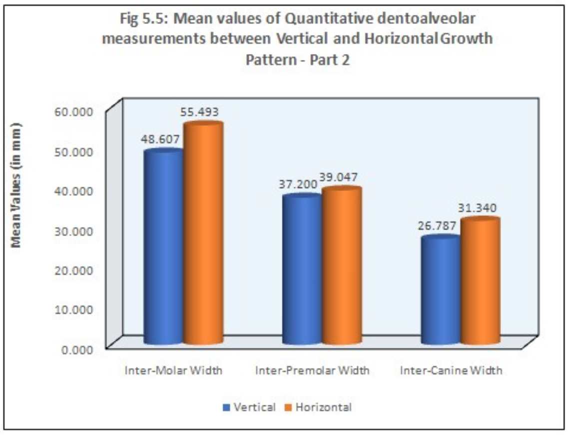

Fig 5.5: Mean values of Quantitative dentoalveolar measurements between Vertical and Horizontal Growth Pattern - Part 2

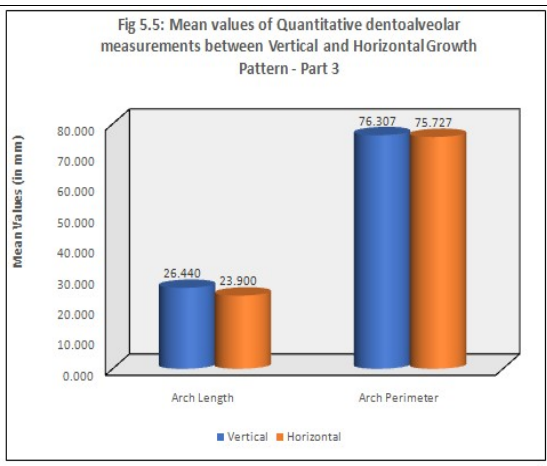

Fig 5.5: Mean values of Quantitative dentoalveolar measurements between Vertical and Horizontal Growth Pattern - Part 3

Premolar basal width also exhibited a significant variation, where the vertical growth pattern had a mean of 38.540 ± 3.126, whereas the horizontal growth pattern recorded a mean of 40.847 ± 2.243. The mean difference of -2.307 was statistically significant (p=0.03). Arch depth showed an inverse trend, with a greater mean in the vertical growth pattern (19.293 ± 1.601) compared to the horizontal growth pattern (17.867 ± 1.594). The mean difference of 1.426 was statistically significant (p=0.02). These findings indicated that growth patterns influenced basal measurements considerably, with distinct variations observed across molar basal width, premolar basal width, and arch depth. (Fig 5.3). The comparison of quantitative dentoalveolar measurements between vertical and horizontal growth patterns revealed varying degrees of statistical significance across different parameters. Molar arch width showed minimal variation between the groups, with a mean of 57.353 ± 3.192 in the vertical growth pattern and 56.947 ± 2.723 in the horizontal growth pattern. The mean difference of 0.406 was not statistically significant (p=0.71). Similarly, premolar arch width exhibited close similarity between the two patterns, with a mean of 44.720 ± 3.025 in the vertical group and 44.413 ± 2.211 in the horizontal group. The mean difference of 0.307 did not reach statistical significance (p=0.75).

In contrast, inter-molar width showed a substantial difference between the groups, where the vertical growth pattern presented a mean of 48.607 ± 1.881, while the horizontal growth pattern demonstrated a significantly higher mean of 55.493 ± 2.588. The mean difference of -6.886 was statistically significant (p<0.001, n=15). Similarly, inter-premolar width displayed a marked difference, with the vertical pattern showing a mean of 37.200 ± 1.380 and the horizontal pattern presenting a mean of 39.047 ± 1.584. The mean difference of -1.847 was statistically significant (p=0.002, n=15). Inter-canine width followed the same trend, with the vertical growth pattern having a mean of 26.787 ± 3.890, while the horizontal growth pattern recorded a higher mean of 31.340 ± 1.429. The mean difference of -4.553 was statistically significant (p<0.001, n=15). Additionally, arch length was significantly greater in the vertical growth pattern, with a mean of 26.440 ± 1.586 compared to 23.900 ± 1.310 in the horizontal growth pattern. The mean difference of 2.540 was statistically significant (p<0.001, n=15). Lastly, arch perimeter demonstrated comparable values between the groups, with the vertical growth pattern showing a mean of 76.307 ± 2.961, while the horizontal growth pattern recorded a mean of 75.727 ± 1.939. The mean difference of 0.580 was not statistically significant (p=0.53). Overall, the findings indicated significant differences in inter-molar width, inter-premolar width, inter-canine width, and arch length, while molar arch width, premolar arch width, and arch perimeter did not exhibit statistically significant differences between the two growth patterns.(Fig 5.4 to Fig 5.6)

DISCUSSION

Maxillary canines that are most impacted tooth in maxillary arch. The morphologic variations in the dentoalveolar and maxillofacial tissues may be linked to this anomaly in dental eruption (2). The maxillary canine, after the maxillary and mandibular third molars, is the tooth that is most frequently impacted(16). Maxillary canine impaction affects 1 to 3% of the general population, according to estimates(17) where unilateral incidences of impaction are more common than bilateral impaction(18). The prevelance in canine impaction is varying from 1.80% to 3.29%, depending on the demographic studied (Hanke et al., 2012).The causes of maxillary canine impaction are primarily explained by two theories: the guidance theory and the genetic theory. The guidance theory, proposed by Peck et al. (1994), suggests that the lateral incisor root guides the canine during eruption, and its absence or malformation can lead to impaction. Miller's classification (Becker, 2022) describes five eruption scenarios based on this theory. In contrast, the genetic theory (19)attributes palatal impactions to inherited traits, as supported by their link to dental anomalies and family history. Peck and Peck (1994) further support this by highlighting a higher prevalence in females and a notable rate of bilateral impaction.

A higher risk of impaction is linked to smaller maxillary width measurements because there is less room in the dental arch. Early detection and interceptive treatment can be used to correct the maxillary width deficiency in order to avoid this issue (12). The dentoalveolar dimension is restricted to the region that contains teeth and has to be expanded via dentoalveolar expansion mechanics. Cone-beam computed tomography (CBCT) is considered the gold standard for localizing impacted maxillary canines due to its superior diagnostic accuracy and clinical usefulness (16). Unlike conventional 2D radiographs, CBCT offers three-dimensional imaging that accurately reveals the tooth's position, root morphology, and proximity to surrounding structures, while eliminating image superimposition (11). It also delivers a lower radiation dose than medical-grade CT, making it suitable for routine use. The comparative analysis of dentoalveolar measurements between vertical and horizontal growth patterns highlighted distinct structural differences across several parameters. Certain measurements, such as molar arch width and premolar arch width, remained consistent across the two growth patterns, suggesting that these dimensions were not substantially influenced by variations in vertical or horizontal skeletal growth tendencies.

On the other hand, inter-molar width exhibited a clear disparity, with individuals demonstrating a horizontal growth pattern showing considerably broader dimensions than those with a vertical growth pattern. This difference may reflect developmental adaptations that favour greater transverse dental arch expansion in horizontal growth patterns, potentially contributing to differences in occlusal function and overall dental stability. A similar trend was observed in inter-premolar width, where individuals with a horizontal growth pattern consistently displayed wider values than those with a vertical growth pattern, reinforcing the idea that arch configuration in horizontal growth patterns may favour increased transverse dimensions. Cacciatore et al.'s study found that early-diagnosed displaced maxillary canines had a narrower and shorter maxillary arch, with significant reductions in intermolar width and arch length compared to controls. The findings suggest that deficiencies in maxillary transverse and sagittal dimensions may contribute to maxillary canine impaction(20). Firincioglulari et al. (2024) observed that patients with labially impacted canines exhibited decreased intermolar width, reduced mid-root palatal width, and a shorter arch perimeter. These anatomical limitations, especially in cases of labial impaction, may play a role in the development of maxillary canine impaction (21). Inter-canine width also varied significantly between the two growth patterns, with the horizontal growth pattern exhibiting broader measurements compared to the vertical growth pattern. This structural distinction may influence dental spacing, alignment, and functional occlusal characteristics, potentially contributing to differences in arch form and stability between individuals with different skeletal growth tendencies. Sambataro et al. found that intercanine width, calculated using posteroanterior cephalograms, was significantly smaller in impacted canines compared to naturally erupting ones. This suggests that anterior segment transverse maxillary constriction may aggravate impaction. The authors recommend early interceptive appliances to target and expand the anterior arch area in susceptible patients (22). Arch length, however, was found to be greater in individuals with a vertical growth pattern. This variation may be associated with differential skeletal development, where vertical growth patterns favour elongated dentoalveolar structures, possibly affecting anterior-posterior arch relationships and bite dynamics. Arch perimeter did not demonstrate substantial differences between the two growth patterns, indicating that overall arch dimensions remained relatively stable regardless of skeletal growth orientation. Despite the observed differences in individual parameters, the consistency in arch perimeter measurements suggests a level of structural balance across the growth types, where adaptations in width and length may compensate for changes in overall arch structure.A study by Bharathi et al. examines the relationship between facial growth patterns, particularly vertical growth, and maxillary canine impactions in Dravidian subjects. It found that 65.71% of patients with canine impaction had a vertical growth pattern, but did not correlate this with arch perimeter or dental arch length. Further research is needed to determine the relationship between these variables (23). Taken together, these findings highlight significant differences in inter-molar width, inter-premolar width, inter-canine width, and arch length between vertical and horizontal growth patterns, while molar arch width, premolar arch width, and arch perimeter remained comparable across the two groups. These variations in dentoalveolar measurements may reflect underlying biomechanical adaptations associated with skeletal growth patterns, influencing functional, Esthetic, and developmental characteristics of the dental arch. The observed differences could have implications in orthodontic planning, occlusal function assessments, and clinical interventions aimed at optimizing dental arch stability and alignment across individuals with varying growth tendencies. This study contributes to the ongoing understanding of the role of dentoalveolar morphology in the etiology of maxillary canine impaction. It supports the premise that dentoalveolar and skeletal variations, particularly in the transverse dimension, significantly influence the risk of canine impaction.

Our results indicate that individuals with vertical growth patterns have significantly narrower distances between canines, premolars, and molars than those with horizontal growth patterns. These reduced transverse measurements indicate a constricted maxillary arch, which may lead to inadequate space for proper eruption paths—ultimately increasing the likelihood of canine impaction. This is consistent with earlier research (8,12), which suggested that transverse maxillary deficiency is a key factor associated with palatally displaced canines.
Additionally, this study underscores that dentoalveolar dimensions, particularly those limited to the tooth-bearing area, are crucial determinants in predicting eruption challenges. These regions may not adapt effectively to vertical growth tendencies, which favor increased arch length over transverse development. In such cases, early detection of maxillary width deficiencies—especially between the ages of 8 and 10—is essential. Interceptive approaches such as dentoalveolar expansion mechanics can be initiated to proactively create space in the dental arch and reduce impaction risk. Despite similarities in overall arch perimeter between growth patterns, the imbalance in width versus length in vertical growers highlights the need for a three-dimensional perspective in orthodontic evaluation. CBCT technology has played a pivotal role in this analysis by offering high-precision imaging for evaluating the spatial relationships and structural limitations within the maxillary arch. This study emphasizes the significant role of dentoalveolar morphology in the etiology of maxillary canine impaction, highlighting that variations in inter-canine, inter-premolar, and inter-molar widths are associated with vertical versus horizontal growth patterns. Vertical growth patterns were consistently linked with reduced transverse arch dimensions and a higher prevalence of canine impaction. Conversely, individuals with horizontal growth patterns tended to exhibit broader transverse measurements, suggesting more favorable conditions for proper eruption paths. Although arch length was found to be greater in vertical growers, this did not compensate for the decreased arch width, reinforcing the need for early identification and management of maxillary width deficiencies to prevent canine displacement. The study explicitly stated the null hypothesis (H_0) that there would be no difference in mean quantitative basal and dentoalveolar measurements between vertical and horizontal growth patterns in patients with maxillary canine impaction, while the alternative hypothesis (H_a) proposed significant differences. Statistical analysis using independent t-tests revealed that H_0 could be rejected for most key measurements, including molar basal width ($p=0.006$), premolar basal width ($p=0.03$), arch depth ($p=0.02$), inter-molar width ($p<0.001$), inter-premolar width ($p=0.002$), inter-canine width ($p<0.001$), and arch length ($p<0.001$), demonstrating significant dimensional differences between growth patterns. However, H_0 was retained for molar arch width, premolar arch width, and arch perimeter, where no statistically significant differences were found ($p>0.05$). These results partially supported H_a, confirming that while vertical growth patterns are associated with significantly narrower transverse dimensions and greater arch length - factors linked to higher impaction risk - not all dentoalveolar measurements varied between growth patterns. The findings were thoroughly discussed in the context of clinical implications, particularly the need for early CBCT-based diagnosis and interceptive treatment for at-risk vertical growth pattern patients. Additionally, the integration of advanced diagnostic tools like Cone-Beam Computed Tomography (CBCT) offers improved accuracy in identifying spatial constraints, root positions, and surrounding anatomical relationships critical for planning interceptive orthodontic strategies. Studies by Cacciatore et al., Firincioglulari et al., and Sambataro et al. supported the findings of transverse constriction and anterior segment space deficiency being major contributors to canine impaction. The use of CBCT further allowed for three-dimensional analysis of arch dimensions, overcoming the limitations of traditional two-dimensional radiographs and enhancing clinicians' ability to plan targeted interventions. Despite valuable insights, the study presents several limitations. One of the limitations of this study was the sample size, the larger sample size is recommended with, limiting the generalizability of the results to broader populations. The geographic focus on a specific demographic (Dravidian subjects) restricts the applicability of the findings to other ethnic or racial groups. Furthermore, the retrospective design of the study may have introduced selection bias or unaccounted variability in patient records and diagnostic criteria. Additionally, arch perimeter was not thoroughly examined across growth patterns in a controlled manner, and the potential influence of other factors such as genetics, oral habits, or environmental contributors was not deeply investigated.

CONCLUSION

This study emphasizes the relationship between dentoalveolar dimensions and the risk of maxillary canine impaction, particularly in relation to skeletal growth patterns. It was observed that individuals with a horizontal growth pattern typically exhibit greater inter-canine width, a trait that potentially facilitates the eruption of maxillary canines by providing sufficient space, thereby reducing the likelihood of impaction. In contrast, those with a vertical growth pattern tend to have narrower inter-canine widths, a characteristic that may contribute to spatial limitations in the anterior region, increasing the risk of impaction. Further analysis revealed that variations in arch length and transverse arch widths are significant factors in this context. Specifically, individuals with vertical growth tendencies are more prone to anterior dental crowding due to reduced transverse dimensions, which may predispose them to canine impaction. These findings suggest a biomechanical link between skeletal growth patterns and dental arch development, reinforcing the need to consider growth patterns as part of comprehensive orthodontic evaluation and risk assessment strategies for impaction. Clinically, these results underscore the critical importance of early diagnostic screening and growth pattern evaluation in orthodontic patients. By identifying maxillary width deficiencies at an early stage, clinicians can implement interceptive treatments such as dentoalveolar expansion to preemptively address spatial limitations. The study advocates for the integration of three-dimensional imaging and growth pattern analysis into routine orthodontic diagnostics to enhance treatment planning, improve patient outcomes, and reduce the incidence of complex anomalies such as maxillary canine impaction. Given that vertical growth patterns appear to prioritize arch length over transverse development, routine evaluation of arch width—particularly inter-canine and inter-premolar distances—should be included in early diagnostics. Orthodontic professionals should consider implementing dentoalveolar expansion techniques proactively in vertical growers to optimize eruption space and reduce the risk of canine impaction. The application of CBCT imaging in such cases further supports a three-dimensional approach to treatment planning, ensuring both structural assessment and risk minimization for impacted teeth.

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