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Maxillary canine angulation and position before alveolar bone grafting in patients with unilateral complete cleft lip and palate a cross-sectional study

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Abstract

Background

The rate of maxillary canine displacement is reported to be higher in patients with cleft compared to normal population. The aim of this study is to compare the displacement tendency of developing maxillary canines in patients with unilateral complete cleft lip and palate (UCLP) versus non-cleft controls before secondary alveolar bone grafting or orthodontic treatment.

Design:

A cross-sectional observational study. **Setting**: University orthodontic clinic. **Materials and Methods**: Eighty-six children aged (8–12 years) were included: 43 with non-syndromic UCLP and 43 non-cleft controls with skeletal Class I relationships. The percentage of patients with high-risk alpha angle (> 30 degrees) of maxillary canines was assessed between study groups as well as between cleft side and non-cleft side in group. The canine horizontal and vertical sector positions were also evaluated.

Results

Maxillary canines in patients with UCLP demonstrated significantly greater alpha angles than those in controls. The odds of an alpha angle > 30 degrees were approximately 15-fold higher in patients with UCLP than in controls and approximately 11-fold higher on cleft than non-cleft sides. Vertical canine position also differed significantly, with a greater proportion of canines occupying more apical sectors on cleft sides. Horizontal sector distribution did not differ significantly between groups. No significant association was found between lateral-incisor agenesis and alpha angle.

Conclusions

Before secondary alveolar bone grafting or orthodontic intervention, UCLP was associated with greater maxillary canine angulation and a more apical vertical position, particularly on the cleft side. These findings suggest that panoramic assessment of canine angulation and vertical position may help identify developing canines at increased risk of ectopic eruption. Longitudinal studies are required to determine their predictive value for subsequent canine impaction.

INTRODUCTION

Background/rationale

Cleft lip and palate (CLP) is one of the most common congenital craniofacial anomalies which often requires prolonged multidisciplinary care. Among other various challenges, patients with CLP often present with a variety of dental anomalies including maxillary canine impaction[1]. The latter anomaly was found to have a higher rate of prevalence compared to the general population (1–5%)[1]. Hereman et al reported a rate of impaction up to 82% while Holz et al further demonstrated a higher rate in cleft versus non-cleft sides (24% vs 13 % resectively) [2, 3].

For several decades, orthodontists emphasized the importance of early identification of high-risk canines which enables timely interceptive strategies, such as the extraction of the deciduous canine or planned surgical exposure [4]. This treatment strategy is vital for integrating the permanent canine successfully into the dental arch and optimizing long-term functional and aesthetic outcomes in comprehensive cleft care. Panoramic radiograph represents the first screening tool for early detection of ectopic eruption of maxillary canines [5]. Different classification systems were reported to study the maxillary canines' eruption patterns in early years which can help clinicians in prognosis-driven treatment decisions as well as timely interceptive strategies [4].

There is a consensus that the horizontal angulation of maxillary canines (commonly described by alpha angle) together with horizontal and vertical sector classification are important predictive factors for canine impaction in patients with cleft[6, 7]. The more the canines are mesially angulated the more they are at risk for impaction in later stages [3, 8]. However, the etiology of this early displacement of canines remain unclear as many related factors might affect the eruption path of maxillary canines including the alveolar defect itself, alveolar bone graft, orthodontic maxillary expansion and lateral incisors agenesis[1]. Rizell et al further demonstrated that the age for both hard palate closure and alveolar bone graft could affect the rate of impaction [9].

Unlike most previous studies evaluating canine position after secondary alveolar bone grafting and/or orthodontic intervention, the present study aims to assess developing maxillary canines before these potential confounders were introduced and includes both within-patient and non-cleft control comparisons.

Objectives

The objective of this study is to compare the position of developing maxillary canines in a group of patients with unilateral complete cleft lip and palate versus a control group before any orthodontic or alveolar surgical treatments.

MATERIALS AND METHODS

Study design

This study is an observational, cross-sectional study with two arms 1:1 comparison. The patients with UCLP were compared with patients without clefts (Control). Comparisons were between cleft and non-cleft sides in patients with UCLP.

Setting/Participants

All patients who were born from 2009 to 2015 and who attended the outpatient orthodontic clinic during the period from 2020 until 2024 were first screened. Eighty-six pre-graft surgery patients who had a panoramic x-ray done as part of their diagnostic records and who met the eligibility criteria were finally included in either study groups i.e. Group I (patients with non-syndromic unilateral complete cleft lip and palate) and Group 2 (skeletal class 1 individuals without any congenital anomalies).

Patients who had dental anomalies other craniofacial anomalies were excluded as well as patients with history of previous orthodontic/orthopedic (including early presurgical infant orthopedics) and early alveolar surgical procedures (such as early grafting of gingivoperiosteoplasty).

All panoramic radiographs were taken using the same machine and standardized head positioning protocol. Image J software (LOCI, University of Wisconsin, USA, version 1.53t) was used for data measurements of digital panoramic images.

All radiographs were first uploaded on the software, then, landmarks and reference planes were determined as shown in (Fig. 1). All measurements were done by two independent assessors. A random sample of 20 patients from either group was measured again by the same observers after 1 month from the first assessment.

The research was approved by the Ethics committee of Faculty of Dentistry.

Variables

Primary Outcome

Described as the percentage of patients who have high risk alpha angles for developing canines (> 30°).

Assessment of horizontal angulation of maxillary canine (Alpha Angle)

The measurement was made between the long axis of the canine and a vertical reference line (Line drawn through the nasal septum and perpendicular to occlusal plane (horizontal line between the mesial buccal cusps of the maxillary first molars) as described by Ericson and Kurol (Fig. 1a) [10]. In severely deviated cases in the cleft group a line was drawn through the most straight part of the nasal septum perpendicular on the occlusal plane.

Secondary Outcomes

Canine Horizontal Position

The projection of canines' cups was divided into five zones in the form of sectors according to the method described by Ericson and Kurol [10] (Fig. 1b), In patients with congenitally missing lateral incisors and where complete space loss and contact between permanent maxillary central incisor and deciduous canine were noticed, the central incisor was used as reference for analysis of canine horizontal position as suggested by Rizell et al [9].

Canine Vertical Position

The maxillary canine crown was assigned to one of five categories, following the method suggested by Power and Short [11](Fig. 1c). In the current study, the reference lines were drawn following the most upright central incisor to avoid the error of measurements in case of missing lateral incisor. The same modification was previously suggested by Hereman et al [3].

Relation of Developmental Position of Canine to Congenitally Missing Lateral Incisors

The presence or absence of lateral incisors were related to the alpha angle of developing maxillary canines.

Bias

All files for patients who came for orthodontic consultation during the study period were considered for inclusion in the study. Only patients whose records were not available were excluded. All outcomes (1ry and 2ry) were measured by two independent observers, blinding was not be possible due to detection of cleft in radiograph.

Study size

Sample size calculation was performed using G. Power® Software with power of 80% and alpha level of significance of 5% (two sided) using data obtained from a previous study on percentages of patients with UCLP having high risk alpha angle (> 30°) compared to control [8]. This resulted in a sample size of 86 patients equally divided into study and control groups

Statistical Methods

Statistical analysis was performed with SPSS 27®, Graph Pad Prism®, and Microsoft Excel 2016. Descriptive values for alpha angles were assessed as means (SD) and were analyzed by Mann Whitney test. All other comparisons were performed by using Chi square test and Fishers Exact test. A cut-off value for alpha angle was set at 30 degrees i.e. alpha angle more than 30 degrees were considered at high risk of impaction, whereas values lower than 30 degrees were low risk. Odds ratios were used to describe the latter outcome. The significant level was set to be at $P \leq 0.05$.

RESULTS

Descriptive data

Both study groups were comparable in age and sex and Nolla dental stage for maxillary canines (Table 1)). In patients with cleft, deciduous canines were absent on 16.23% on non-cleft sides compared to only 2,33% observed on the cleft sides. The lateral incisor was absent in 30.2% of patients with cleft, among them, 48.8% of cleft sides had missing lateral incisors compared to 11.6% of non-cleft sides (Table 1).

Inter and intra-reliability test showed good agreements among observations.

The intra-class correlation coefficient (ICC) was 1.000 (95% CI 1.000–1.000), 0.913 (95% CI 0.864–0.945) and 0.983 (95%CI 0.973–0.989) for inter-observer measurements of alpha-angle, horizontal and vertical position respectively and was 0.999 (95%CI 0.998–0.999), 0.910 (95%CI 0.859–0.942) and 0.947 (95% CI 0.917–0.966) respectively for intra-observer agreement of latter outcomes.

Table 1
Baseline data for study groups

Sex		**Patients with cleft (43)**		**Control (43)**		**P value**
N (%)	**Male**	**23 (53.5%)**		**23 (53.5%)**		
Female	**20 (53.5%)**		**20 (46.5%)**			
Age M ± SD		9.16 ± 0.97		9.23 ± 1.07		0.75
Cleft-Side distribution	Right	14 (32.6%)		-		
N (%)	Left	29 (67.4%)		-		
Nolla developmental stages	Stage 6	4 (4.7%)		0(0.0%)		0.11
	Stage 7	39 (45.3%)		32 (37.2%)		
	Stage 8	36 (41.9%)		43 (50.0%)		
	Stage 9	7(8.1%)		11 (12.8%)		
Alpha angle (Mean ± SD)		23.46 (10.75)		13.70 (8.07)		0.0001**
		Cleft side (43)	Non-Cleft side (43)	Right (43)	Left (43)	0.0001[a]
		28.81 ± 10.06	18.12 ± 8.63	13.53 ± 7.57	13.88 ± 8.63	0.82[b]
Lateral incisor	Absent	21 (48.8%)	5 (11.6%)	0		0.001**
N (%)	Present	22 (51.2%)	38 (88.4%)	86 (100%)		
Deciduous canine	Absent	1 (2.33%)	7 (16.28%)	8(18.6%)	10(23.26%)	0.03*
N(%)	Present	42 (97.67%)	36 (83.72%)	35(81.4%)	33(76.74%)	

*= P value for the outcome mean value of alpha angle was calculated by Mann Whitney test whereas other categorical outcomes (Nolla development and missing lateral incisors) were calculated by Chi square test and Fishers Exact test

**=Statistically significant

CS=Cleft side

NCS = NCS

RT=right side control

LT=Left side control

[a]= P value for cleft side/non-cleft side

[b]= P value for right/left sides in control

Main results

Intragroup Comparison

Alpha Angle (α)

Mean values for alpha angle were significantly higher on cleft sides compared to non-cleft ones (28.81 ± 10.06 versus 18.12 ± 8.63 respectively) (Table 1). Forty six percent of canines on cleft sides had high risk alpha angles compared to only 7% on non-cleft sides. Odds ratio for high- risk alpha angle (> 30°) was 11.59 (CI 95% 3.1 to 43.29). No differences were found among control (Table 2).

Horizontal Sector and Vertical Sectors

No significant differences were found in horizontal position. Sector 1 was most common on both sides in cleft group (79.1% cleft vs. 65.1% non-cleft) as well as in control group (67.4% on the right side and 72.1% on the left) (Table 2).

As for vertical position, Sector 4 was more frequent on the cleft side (25.6% vs. 4.7%). For control group, the distribution across vertical sectors showed no differences (*P* = 0.48) (Table 2).

Intergroup Comparison (Per-patient Analysis)

Cleft Group Versus Control Group

A statistically significant difference was observed in the alpha angle between the two groups (23.46 (10.75) versus 13.70 (8.07) respectively) (Table 1). In the cleft group, 26.7% had an angle > 30° compared to 2% in control. Cleft group was 15 times more likely to have angle > 30° (CI 95% 3.48–67.45) (Table 3).

A significant difference was detected in vertical positioning between the groups. In the cleft group, most teeth were in Sector 3 (44.2%) and Sector 2 (38.4%) while, in control, the percentage was 54.7% and 31.4%, respectively (Table 3).

No significant differences were found between groups regarding the horizontal sectors (Table 3).

Intergroup Comparison (Per-mouth-side Analysis)

Comparison between Cleft Side Group, Left Side Control Group, and Right Side Control Group (Table 4**)**:

Alpha Angle (α)

In the cleft side, 46.5% of cases had an alpha angle > 30°, while only 2.3% were found in control sides (*P* = 0.0001).

Vertical Sector

The cleft side had a higher percentage in sector 4 (25.6%) compared to left (4.7%) and right (4.7%) controls (*P* = 0.003). Sector 1 was absent on cleft sides.

No significant differences were found between groups regarding the horizontal sectors.

Comparison between Non-cleft Side Group, Left Side Control Group, and Right Side Control Group (Table 4**)**:

No significant differences were found among groups for any of the variables studied.

Most teeth on cleft and control sides had Alpha angle < 30°. In the non-cleft group, most teeth were in horizontal sector 1 (65.1%), followed by sector 2 (32.6%). Similar patterns were seen in control sides. As for vertical Sector: most cases were in sector 3 (51.2%, 46.5% and 62.8% for non-cleft, left control and right control sides respectively.

Relation of Missing Lateral and Alpha Angle in Cleft Group (Table 5)

No relation was found between lateral incisor agenesis and alpha angle ($\chi^2 = 2.61$, df = 1, *P* = 0.11). Alpha angles > 30 were observed in 43.5% of patients with lateral incisor agenesis and in 56.5% in patients without agenesis.

Table 2
Intra-group comparison: Chi square test and Fishers Exact tests

		Control group					Cleft Group					
		Side				P value	Side				Odds Ratio	P value
		Right		Left			Cleft		Non-Cleft			
		Count	Column N %	Count	Column N %		Count	Column N %	Count	Column N %		
		43		43			43		43			
α	less than 30	42	97.7%	42	97.7%	----	23	53.5%	40	93.0%	11.59 (3.1 to 43.29)	< 0.0001*
	More than 30	1	2.3%	1	2.3%		20	46.5%	3	7.0%		
HS	Sector 1	29	67.4%	31	72.1%	0.87	34	79.1%	28	65.1%		0.24
	Sector 2	11	25.6%	9	20.9%		8	18.6%	14	32.6%		
	Sector 3	3	7.0%	3	7.0%		1	2.3%	0	0.0%		
	Sector 4	-	-	-	-		0	0.0%	1	2.3%		
VS	Sector 1	3	7.0%	5	11.6%	0.48	0	0.0%	2	4.7%		0.02*
	Sector 2	11	25.6%	16	37.2%		16	37.2%	17	39.5%		
	Sector 3	27	62.8%	20	46.5%		16	37.2%	22	51.2%		
	Sector 4	2	4.7%	2	4.7%		11	25.6%	2	4.7%		

α = Alpha angle, HS=Horizontal sector, VS=Vertical sector

Table 3
Intergroup comparisons (Per-patient analysis). Chi square test and Fishers Exact tests

		Group				P value	Odds Ratio (CI)
		cleft group		control group			
		Count (86)	Column N %	Count (86)	Column N %		
α	less than 30	63	73.3%	84	97.7%	0.0001*	15.3 (3.48) to 67.45)
	more than 30	23	26.7%	2	2.3%		
HS	Sector 1	62	72.1%	60	69.8%	0.19	-
	Sector 2	22	25.6%	20	23.3%		
	Sector 3	1	1.2%	6	7.0%		
	Sector 4	1	1.2%	0	0.0%		
VS	Sector 1	2	2.3%	8	9.3%	0.01*	-
	Sector 2	33	38.4%	27	31.4%		
	Sector 3	38	44.2%	47	54.7%		
	Sector 4	13	15.1%	4	4.7%		

α = Alpha angle, HS=Horizontal sector, VS=Vertical sector

Table 4
Intergroup Comparison (per-mouth-side analysis): Chi square test and Fishers Exact tests

		Group						P Value	Group						
		cleft side/ cleft group		**left side / control group**		**right side. control group**			**Non-cleft side/ cleft group**		**left side / control group**		**right side. control group**		**P Valu**
		Count	Column N %	Count	Column N %	Count	Column N %		Count	Column N %	Count	Column N %	Count	Column N %	
α	**Less than 30**	23	53.5%	42	97.7%	42	97.7%	< 0.0001*	40	93.0%	42	97.7%	42	97.7%	**0.44**
	More than 30	20	46.5%	1	2.3%	1	2.3%		3	7.0%	1	2.3%	1	2.3%	
HS	**Sector 1**	34	79.1%	31	72.1%	29	67.4%	0.73	28	65.1%	31	72.1%	29	67.4%	**0.39**
	Sector 2	8	18.6%	9	20.9%	11	25.6%		14	32.6%	9	20.9%	11	25.6%	
	Sector 3	1	2.3%	3	7.0%	3	7.0%		0	0.0%	3	7.0%	3	7.0%	
	Sector 4	-							1	2.3%	0	0.0%	0	0.0%	
VS	**Sector 1**	0	0.0%	5	11.6%	3	7.0%	0.003*	2	4.7%	5	11.6%	3	7.0%	**0.68**
	Sector 2	16	37.2%	16	37.2%	11	25.6%		17	39.5%	16	37.2%	11	25.6%	
	Sector 3	16	37.2%	20	46.5%	27	62.8%		22	51.2%	20	46.5%	27	62.8%	
	Sector 4	11	25.6%	2	4.7%	2	4.7%		2	4.7%	2	4.7%	2	4.7%	

α = Alpha angle, HS=Horizontal sector, VS=Vertical sector

Table 5
Relation between missing lateral and alpha angle in Cleft group

Lateral incisor	Alpha angle				Chi square test		
	less than 30		**more than 30**				
	Count	Column N %	Count	Column N %	Chi-square	df	Sig.
Absent	16	25.4%	10	43.5%	2.61	1	0.11
Present	47	74.6%	13	56.5%			

DISCUSSION

Key results

Greater proportions of patients with UCLP had canines with critical alpha angle (> 30) compared to control (26.7% and 2.3% respectively) and cleft sides were particularly more prone to canine displacement than the corresponding non-cleft sides (46.7% and 7% respectively). Significant differences were also observed in vertical sector position but not in the horizontal position. Greater proportions of canines were more apically positioned than control (15.1% versus 4.7% respectively).

Canine impaction can significantly contribute to this extended burden as the management typically requires a combination of surgical exposure, orthodontic traction and often a prolonged fixed appliance therapy [12]. The rate of canine impaction was reported to be higher than the normal population. For instance, Heremen et al. and Holz et al reported impaction rates of 43% and 24% respectively on the cleft sides[2, 3]. Rizell et al. further reported that 28% of cleft-side canines required surgical exposure [9].

In fact, there is limited evidence about the canine position and angulation in early years of development in patients with CLP back to inadequate study designs (lack of control group and heterogenous study groups) and underpowered studies. Notably, the presence of different confounders such as orthodontic and surgical treatment steps, which are conventionally performed throughout these early years, further complicates the findings and hinder drawing conclusions about the actual culprit for canine impactions in this patient population.

The results of our study substantiate the previous findings and provide compelling evidence regarding the greater tendency of maxillary canine displacement in patients with UCLP. As previously mentioned, most of the literature reporting on maxillary canine displacement in patients with cleft was based on observations made in later stages of treatment i.e. when surgical intervention (secondary alveolar graft in particular) and different types of orthodontic treatment, which are known factors to affect canine eruption, had already been performed[2, 13, 14]. Additionally, the assessment of canines on cleft sides were conventionally compared to a non-cleft sides but not to a control group of patients without clefts.

The current research was designed to study the possible effect of alveolar cleft itself on the developing maxillary canine's position even before the previously mentioned confounders could be present. First, a control group of patients with skeletal class I relation was used for comparison as it was concluded that some dento-facial discrepancies and congenital anomalies might be associated with higher risk of canine impaction [15, 16]. Second, the inclusion of early age group of patients provides an assessment of maxillary canines prior to 2ry alveolar bone grafting (SABG) and orthodontic expansion/protraction procedures. Third, the exclusion of other types of cleft anomalies was done to avoid the confounding effects of cleft type affecting the position of canine[17]. Moreover, per-mouth sides statistical analysis enabled us to have more insights into the possible effects of alveolar cleft itself on the development of maxillary canines. This becomes evident while comparing cleft sides and non-cleft sides versus control.

For several decades, the authors attempted to evaluate the ectopic eruption of maxillary canines during the early stages of development by adopting several classifications system based upon their positions, angulations and closeness to significant anatomic landmarks [7]. Among these assessment tools, the canine inclination angle, commonly referred to as the alpha (α) angle, was used as a reliable indicator for early diagnosis and prediction of canine eruption patterns. Pastuszak et al. found that 87% of unerupted canines with an angle over 30° were on the cleft side [18]. Westerlund et al. established an alpha angle > 30° as a significant risk marker for later surgical exposure [14]. Our results agree with previously mentioned findings as the assessment of the alpha angle revealed that a significantly higher proportion of individuals in the cleft group compared to the control group. Patients with UCLP were 15 times more prone to increased alpha angle (> 30°) than control. Furthermore, the odds for cleft sides to reach the latter critical angulation were 11 compared to non-cleft sides in patients with UCLP. However, these results should be interpreted with caution as wide range of confidence intervals were observed which might be due to the relatively fewer canines at right risk in control group.

Regarding the vertical positioning of the maxillary canine, a notable difference was found between groups, with a threefold higher prevalence of Sector 4 positioning in the cleft group which indicates that the apical canine position is strongly linked to the cleft anomaly. In parallel, Hereman et al found that a vertical apical position more than one-third of the root of the lateral incisor served as a significant risk indicator [3], a finding that was corroborated by Rizell et al [9].

Our work substantiates the findings that alpha angle and vertical sector might be used as early and objective radiographic indicators for potential risk of ectopic eruption of maxillary canine in patients with UCLP. However, future controlled longitudinal studies are required to further demonstrate the validity of these two parameters as early prediction of possible canine impaction.

It is worth noting that important conclusions could be drawn from comparing both the cleft and non-cleft sides to control. The cleft sides showed significant differences in canine angulation and vertical position compared to control. The absence of such differences on the non-cleft-sides shed light on the possible etiology of ectopic development of maxillary canine in patients with cleft i.e. the alveolar cleft itself rather than genetic susceptibility might be the culprit for higher risk of future canine impaction.

As for the horizontal sector analysis, our findings showed no significant differences in any of the groups studied. Holz et al reported similar findings whereas other studies concluded conflicting results [2]. Some authors found the horizontal sector is less reliable than other measures in predicting the impaction of maxillary canines [3]. However, horizontal assessment still has clinical value when used to monitor changes, particularly after alveolar surgery, as suggested by Russell and McLeod [19].

Several theories regarding the etiology of ectopic eruption of maxillary canines have been documented, with lateral incisor guidance and genetic factors being the most frequent [20]. The link between lateral incisor agenesis and maxillary canine impaction, particularly in patients with cleft lip and palate, remains an ongoing debate [3, 14]. In the current study, the prevalence of lateral incisor agenesis was significantly higher on the cleft side (48.8%) compared to the non-cleft side (11.6%). However, the relation of missing lateral and alpha angle in Cleft group reveals insignificant difference between them. Again, these findings might suggest that the alveolar cleft defect can play a stronger role than lateral incisor agenesis.

In summary, within the limitation of our study, the presence of cleft lip/palate anomaly might affect early canine angulation and the vertical position of developing maxillary canines compared to children with skeletal class I. This can occur at early stages of development and before the influence of other possible risk factors for ectopic eruption of canines such as orthodontic protraction, secondary alveolar graft as well as intra-arch discrepancies.

Limitations

The main limitation is the cross-sectional design, which precludes tracking the dynamic canine eruption over time. Future longitudinal studies are recommended to assess factors influencing eruption, including timing of orthodontic/surgical interventions, alveolar bone graft characteristics, and lateral incisor development. Panoramic radiographs are essential for assessing maxillary canine position in patients with cleft lip and palate (CLP) [7, 21]. However, the buccopalatal position of canines along with possible root resorption of adjacent teeth could not be accurately evaluated because of the superimpositions imposed by two-dimensional (2D) panoramic radiograph. Clinicians should consider the 2D limitations of panoramic images, opting for CBCT when more complex situations arise or precise 3D data is necessary for treatment planning, particularly for surgical interventions in CLP patients.

Generalizability

The results of this study were based on patients with a single type of cleft i.e. unilateral cleft lip and palate and the study was performed in one university hospital center. Future multicentered studies reporting on different types of clefts could add to the existing evidence.

CONCLUSIONS

- There was a significant difference in the displacement tendency of maxillary canines in patients with cleft as described by the increased horizontal canine angulation (alpha angle) and more apical position compared to control. Similar discrepancies were found between the cleft and non-cleft sides as well as between the cleft side and control.
- The canine horizontal position showed no differences between patients with cleft and control.
- Non-cleft side showed similar canine position and angulation compared to control.
- There was no relation between the presence or absence of lateral incisor and the degree of alpha angle.
- The presence of an alveolar cleft was associated with greater canine angulation and a more apical vertical position. Future well conducted longitudinal studies are required to study the possible effects of secondary alveolar graft surgery as well as other orthodontic/surgical treatment on the impaction of maxillary canines.

Declarations

- **Ethics approval and consent to participate**

The research was approved by “Research Ethics Committee (REC), Faculty of Dentistry, Cairo University” (approval no.12/9/23). All procedures performed in the study involving human participants were in accordance with the institutional and/ or national research committee’s ethical standards and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The requirement for informed consent to participate was waived due to the retrospective nature of the study and the use of anonymized radiographic records

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Figures

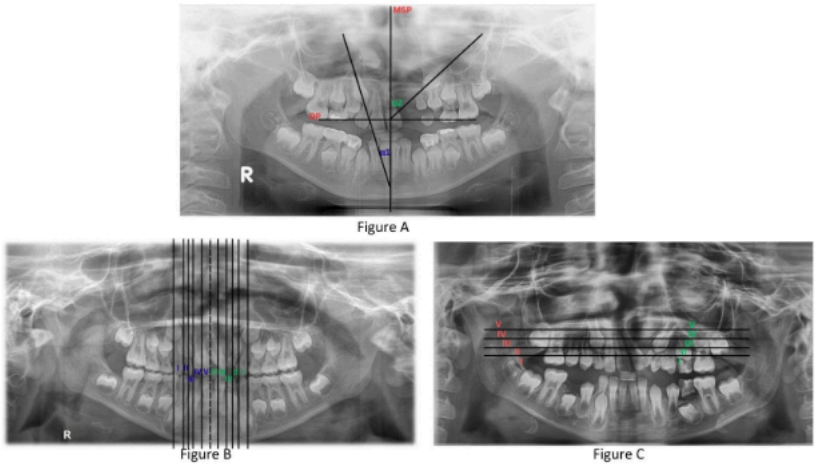


Figure 1

1-A: Landmarks and reference planes on panoramic radiograph, MSP: Midsagittal plane, OP: Occlusal plane, α1: Alpha angle in non-cleft side, α2: Alpha angle in cleft-side, 1-B: Sectors for canine horizontal positions as described by (Ericson and Kurol, 1988), blue numbers denote horizontal sectors on non-cleft side and green numbers denote sectors on cleft-side, 1-C: Sectors for vertical canine positions as described by Power and Short