BMC Oral Health

RESEARCH

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The evaluation of posterior superior alveolar Canal in patients with unilateral cleft lip and palate using cone-beam computed tomography

Hacer Nida Akdogan[1*], Damla Soydan Cabuk[2], Berkhas Tumani Ustdal[3] and Aykagan Cukurluoglu[4]

Abstract

Background This study evaluates the location and supero-inferior diameter of the posterior superior alveolar canal (PSAC) in adolescent patients with unilateral cleft lip and palate (CLP) using cone-beam computed tomography (CBCT).

Methods CBCT scans of sixty adolescent patients (30 male, 30 female) having unilateral CLP were included in the study. The visibility of PSAC, its location relative to the maxillary sinus (upper, middle and lower parts of the sinus and alveolar crest level), and the supero-inferior diameter of the PSAC were evaluated. Additionally, the entry point of the PSAC into the maxillary sinus was assessed relative to the teeth.

Results The average age of the patients was 15.5 ± 1.6 years. PSAC is located significantly more in the middle (61.7%) and superior (38.3%) third of the maxillary sinus in cleft side (CS) ($p < 0.001$). The mean PSAC supero-inferior diameter in the CS (1.08 ± 0.2 mm) was significantly higher than in the non-cleft side (NC) (0.96 ± 0.2 mm) ($p < 0.001$). When the position of the PSAC relative to the teeth was evaluated, it was seen that it entered the maxillary sinus more from the first premolar tooth level in CS and from the first molar tooth level in NC ($p < 0.05$).

Conclusion PSAC location in CS was most commonly found in the middle and superior thirds of the maxillary sinus compared to NC. The mean supero-inferior diameter of PSAC was larger in CS compared to NC. The entry point of PSAC into the maxillary sinus was more anteriorly positioned in CS compared to NC.

Keywords Cleft palate, Cone-beam computed tomography, Posterior superior alveolar canal

*Correspondence:
Hacer Nida Akdogan
nidaauguz@gmail.com
[1]Department of Pediatric Dentistry, Faculty of Dentistry, Cukurova University, Adana, Turkey
[2]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Çukurova University, Adana, Turkey
[3]Department of Oral and Maxillofacial Radiology, Fatma Kemal Timuçin Oral and Dental Health Hospital, Adana, Turkey
[4]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Erciyes University, Kayseri, Turkey

Background

Cleft lip and palate (CLP) represents the most prevalent craniofacial anomaly, manifesting in roughly one in 700 live births globally [1, 2]. The etiology of CLP is believed to involve an interplay between genetic modifications and environmental influences [3, 4]. Therefore CLP is complex and depends on different embryological origins and developmental times.

CLP patients experience maxillary hypoplasia because the shape, growth pattern, and dimensions of the maxilla are profoundly affected. It has also been noted that procedures performed due to the CLP significantly impair maxillary development, and these morphological changes persist even after the completion of treatment [5–7]. The borders of the maxillary sinus within the maxillary bone are similarly affected by CLP. Studies comparing CLP patients with non-cleft individuals have reported significantly smaller maxillary sinus volumes in individuals with CLP. Furthermore, in patients with unilateral clefts, the sinus volume on the cleft side has been found significantly lower [8–10]. Additionally, a study on mouse embryos with CLP reported vascular changes such as widening of neurovascular channels visualized in histological sections of the nasopalatine canal in the maxilla [11]. There are also studies examining anatomical structures such as infraorbital foramen and nasopalatine canal in patients with CLP [12, 13]. In these studies, it was found that the nasopalatine canal had a wider diameter and a shorter canal length in CLP patients [12], while the infraorbital foramen was located more superiorly on the cleft side [13]. In recent years, the use of cone-beam computed tomography (CBCT) has become widespread in maxillofacial imaging studies, as it offers higher image resolution, lower radiation dose, shorter scanning time, and reduced cost compared to conventional computed tomography (CT) [8–10, 12, 14].

Surgical treatment of CLP is complex and lacks standardization, often depending on the surgeon's expertise to determine the type and timing of surgery [15]. Treatment is commenced at around 5 years of age and extends over a period of more than 10 years [16]. In this period, many surgical procedures such as fissure closure, bone grafts, osteotomy techniques, flaps at the maxillary sinus level, placement of dental implants, placement of microimplants for anchorage in orthodontics, and Le Fort I type surgeries are performed on patients with CLP to correct maxillomandibular disorders, functional and aesthetic changes [17]. Anatomical differences in patients with CLP should be well defined to avoid possible complications such as bleeding and neurosensory disturbances during these procedures. The changes in the overall size of the maxilla and maxillary sinus due to CLP may alter the position of neurovascular structures, such as the posterior superior alveolar canal (PSAC) [18, 19]. The PSAC, which crosses along the lateral wall of the maxillary sinus, generally contains sensory branches of CN V2 and gives sensory innervation to the maxillary sinus and maxillary molars teeth. At the same time, the PSAC contains the posterior superior alveolar artery (PSAA), which has the potential for bleeding during and after surgeries in CLP patients [20, 21]. Knowing the variations of PSAC in CLP patients before surgery via CBCT is important for preoperative planning. In this way, changes in preoperative planning such as changing the osteotomy line and changing the planned implant location can be made to prevent complications such as bleeding and neurosensory damage [17].

There are also many studies describing the characteristics of the PSAC in non-cleft individuals [20, 22, 23]. However, only a number of studies have examined the PSAC, which holds a critical position relative to the surgical area for CLP, in patients with CLP to the authors' knowledge [17, 24]. Gittins et al. and Tannishtha et al. also compared the differences in PSAC location and diameter between patients with CLP and non-cleft. However, the differences between the cleft side (CS) and non-cleft side (NC) in unilateral CLP patients were not evaluated in these previous studies. The present study aimed to investigate the anatomical differences in PSAC on CS and NC in unilateral CLP patients under the age of 18, focusing on location, supero-inferior diameter and clinical implications. The null hypothesis of the research was that there was no anatomical difference between the location and supero-inferior diameter of PSAC on the CS and NC.

Methods

The present study was initiated after receiving approval from the Cukurova University Ethics Committee (date: 05/11/2021, meeting no: 116, decision no: 69). CBCT images of patients who applied to Cukurova University, Faculty of Dentistry due to orthodontic treatment and reconstructive surgery needs were used in the study. Images were obtained from the archives of the Department of Oral and Maxillofacial Radiology and were evaluated retrospectively. All the patient's parents in this study had signed an informed consent regarding the use of their CBCT data for scientific research.

Power analysis was performed using the G*Power 3.1.9.2 (Heinrich-Heine-University, Dusseldorf, Germany) program. 120 sides of 60 participants in total were calculated for a sample size of 60 per group with 0.8 effect size, 95% power, and a 5% significance level [17]. A total of 60 CBCT images (Planmeca ProMax® 3D Mid, Helsinki, Finland; Voxel size: 0.2 mm^3; exposure parameters: 90 kV, 10 mA, 27 s scan time, FOV: 20×17 cm) were examined. All image analyses were performed in a dark

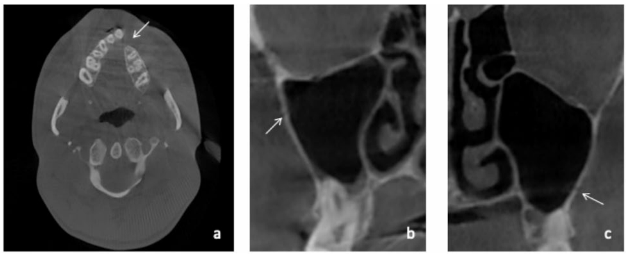

Fig. 1 (**a**) Axial CBCT image showing unilateral CLP on the left side (white arrow), (**b**) Coronal CBCT image showing PSAC entry in maxillary sinus on NC (white arrow), (**c**) Coronal CBCT image showing PSAC entry in maxillary sinus on CS (white arrow)

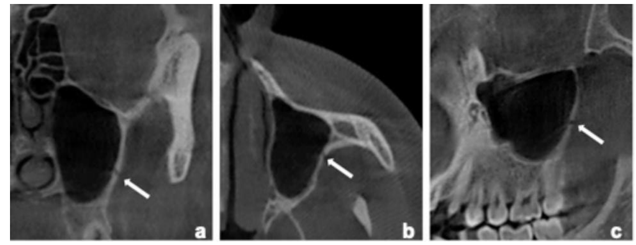

Fig. 2 The CBCT images showing the PSAC in coronal (**a**), axial (**b**), and sagittal (**c**) sections

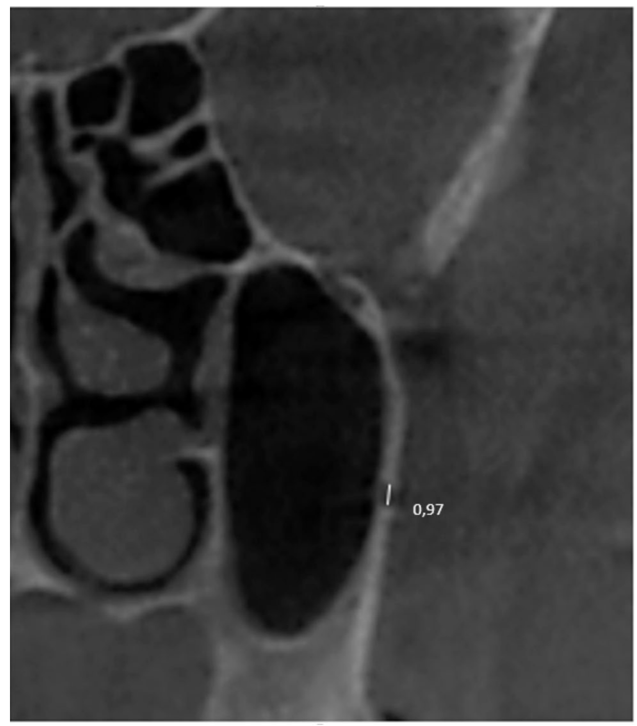

Fig. 3 The coronal CBCT image showing the measurement of the PSAC supero-inferior diameter

and quiet room using the Romexis viewer software on a 22-inch LG Flatron monitor (LG, Seoul, Korea).

All the measurements were performed by two oral and maxillofacial radiologists with a mean of 6 years of experience. All the measurements were performed independently using the same station by two examiners. Any instance of an intraobserver discrepancy between the readings was subjected to a post hoc consensus review with both observers to determine the cause of the discrepancy, and a final decision was made by the consensus of the observers. Beforehand, a calibration process was independently performed to identify maxilla anatomical structures. CBCT images of 30 patients with unilateral CLP who were not included in the study were analyzed for intra- and inter-calibration. In the presence of a disagreement, the disagreement between examiners was resolved through discussion. Therefore a consensus was reached. The measurements were performed twice at two-week intervals. Kappa compatibility values, reference ranges; <0 is interpreted as 'worse fit than chance fit', 0.01–0.20 as 'negligible', 0.21–0.40 as 'poor fit', 0.41–0.60 as 'moderate fit', 0.61–0.80 as 'high level of fit', 0.81-1.00 as 'very high level of fit' [25]. The intra- and inter-calibration kappa compatibility level between both examiners was found to be very high level of fit (κ: 0.910; κ: 0.921, respectively).

Unilateral CLP patients who had CBCT scans for various reasons between 2019 and 2021 were included. At the beginning of the study, 88 patients with unilateral CLP were found. All participants included in the study were patients with unilateral CLP without any other craniofacial syndrome. Exclusion criteria from the study were determined for patients with trauma in the maxillofacial region, patients with the craniofacial syndrome, low-quality CBCT images (images with metallic artefacts, motion artefacts), and CBCT scans where the entire maxillary sinuses could not be visualized. After applying the inclusion and exclusion criteria, 120 sides of 60 patients with unilateral CLP were determined (aged between 13 and 18 years). Two groups were established: NC and CS (Fig. 1).

First of all, the presence or absence of PSAC was determined from axial, sagittal, and coronal sections on CBCT images (Fig. 2). When it was present; the location of the PSAC relative to the maxillary sinus (superior, middle and inferior parts of the sinus and the alveolar crest level) were determined from the coronal section. In the coronal sections where the PSAC was identified, the distance between the most superior and inferior points of the maxillary sinus was measured. The maxilla was then divided into three equal parts based on these linear measurements, and the PSAC was evaluated within each section. Coronal sections where the PSAC supero-inferior diameter was thought to be the widest were determined. Supero-inferior diameter width was measured in the determined sections and the widest measurement was recorded for statistical evaluation (Fig. 3).

The entry point of PSAC into the maxillary sinus was evaluated according to Gittins et al. [17]. The reference points were determined in accordance with the mesial aspect of each tooth: upper right third molar (18) to upper right second molar (17), upper right first molar (16), upper right second premolar (15), and upper right first premolar (14), upper left third molar (28) to upper left second molar (27), upper left first molar (26), upper left second premolar (25), and upper left first premolar (24) (Fig. 4). If there was no tooth at the relevant entry point, the distal surface of the nearest tooth was taken as the reference point. If there were two missing teeth in that area, half the distance between them was calculated and the reference tooth point was taken as a basis.

Statistical analysis

Statistical evaluations were conducted using IBM Statistical Package for social sciences (SPSS) software, version 25.0 (Chicago, IL, USA). Categorical variables were quantified as frequencies and percentages, and continuous variables as means and standard deviations, or medians and ranges where necessary. Categorical data were analyzed using the chi-square test, and normality was assessed with the Shapiro-Wilk test. Reliability was measured using Cohen's Kappa coefficient for both intra- and inter-rater comparisons. Mann-Whitney U test was used in pairwise group analysis for parameters that did not show normal distribution. The statistical significance level was $p < 0.05$ in all tests.

Results

In the study, CBCT images of 60 adolescents with unilateral CLP, aged between 13 and 18, were evaluated. 30 were males (50%) and 30 were females (50%). The average age of participants was 15.5 ± 1.6 years old (Table 1).

PSAC was visible in 100% of the CS and NC.

In the CS, the PSAC was located in the middle third of the maxillary sinus in 61.7% of cases, compared to 43.3% in the NC ($p < 0.001$). In the CS, the PSAC was located in the superior third of the maxillary sinus in 38.3% of cases, compared to 6.7% in the NC ($p < 0.001$) (Table 2).

When the position of the PSAC in relation to the teeth was evaluated, it was observed that 55% of the CS cases entered the maxillary sinus from the first premolar level, while this rate was 35% in the NC ($p = 0.022$). In contrast, it was observed that 25% of the NC cases entered the maxillary sinus from the first molar level, while this rate was 11.7% in the CS ($p = 0.049$) (Table 2).

The mean supero-inferior diameter of the PSAC was 1.08 ± 0.2 mm in the CS and 0.96 ± 0.2 mm in the NC, representing a statistically significant difference ($p < 0.001$) (Table 2).

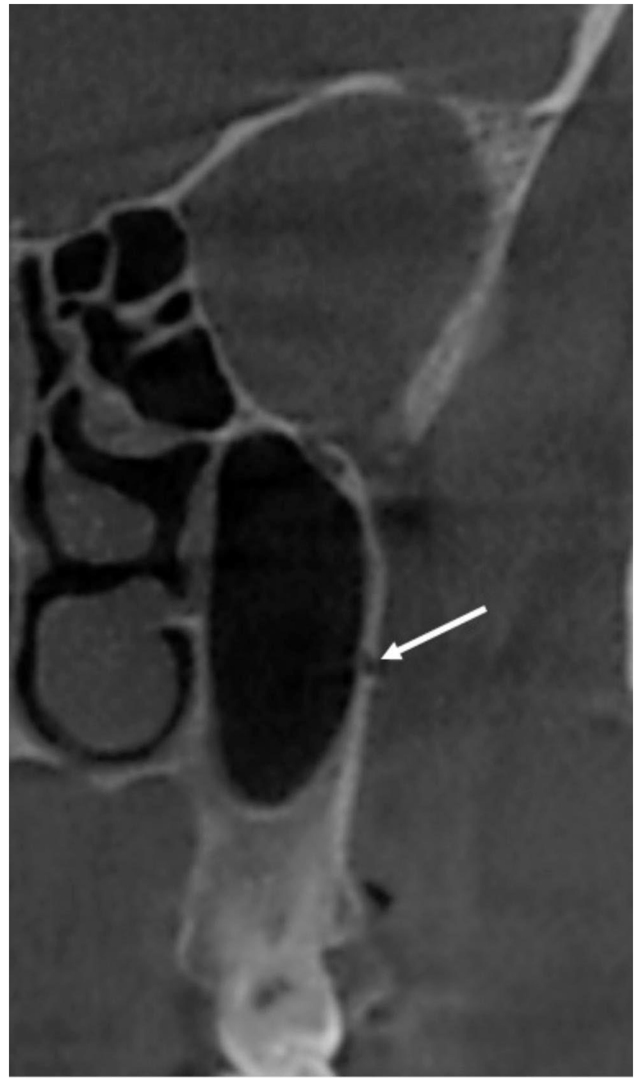

Fig. 4 The coronal CBCT image showing the PSAC entrance in the maxillary first molar level

Table 1 Demographic data of patients

	n	%
Gender		
Female	30	50,0
Male	30	50,0
	Mean ± SD	**Med (Min-Max)**
Age	15,5 ± 1,6	15 (13–18)

SD: Standard Deviation

Discussion

The preoperative assessment of maxilla neurovascular structures is crucial for planning dental interventions such as surgical procedures, and restorative and pulpal treatments of maxillary teeth. The clinician's knowledge of the anatomical variations of the area may affect the success of the treatment and prevents complications. Patients with CLP, which is considered the most

Table 2 Location of the PSAC entry point relative to the maxillary sinus and teeth, and PSAC supero-inferior diameter in CS and NC

	CS ($n=60$)	NC ($n=60$)	*P*-value
Maxillary sinus	**n(%)**	**n(%)**	
Alveolar crest	-	-	**< 0.001****+
Inferior	-	30 (50)	
Middle	37 (61.7)	26 (43.3)	
Superior	23 (38.3)	4 (6.7)	
Tooth position	**n(%)**	**n(%)**	
P1	33 (55)	21 (35)	**0.022***+
P2	20 (33.3)	23 (38.3)	0.568+
M1	7 (11.7)	15 (25)	**0.049***+
M2	-	1 (1.7)	0.500+
PSAC supero-inferior diameter (mm) (Mean ± SD)	1.08 ± 0.2	0.96 ± 0.2	**0.001****++

*$p < 0.05$;**$p < 0.01$. +: Chi-square test, ++: Mann Whitney U, CS: cleft side, NC: non-cleft side, P1: 14/24 first premolar, P2:15/25 second premolar, M1: 16/26 first molar, M2: 17/27 second molar, PSAC: posterior superior alveolar canal, SD: Standard Deviation

common craniofacial malformation of the face, are subjected to various rehabilitation operations involving the maxilla, such as alveolar bone grafting, orthognathic surgery, and dental implants [26]. Before these operations, it is important to identify the neurovascular differences of the maxilla by radiographic evaluation to prevent possible bleeding and neurosensory disorders [23]. In studies evaluating the dental caries and periodontal status of children and adolescents with CLP, a higher risk of caries and gingival inflammation was observed in those with CLP compared to those without [27, 28]. Knowing the neurovascular anatomy of these patients can also help prevent anaesthesia failures that may occur during restorative and pulpal treatments of maxillary teeth [17, 23, 29–31].

Based on the current literature, this study appears to be the first to utilize CBCT to investigate cleft and non-cleft side PSAC in adolescents on both the cleft and non-cleft sides within the same patient. There are many studies in the literature describing the neurovascularization of the maxilla in individuals without CLP. While CT was used in some of these studies [20, 32, 33], CBCT was used in others [22, 23, 34, 35]. In recent years, the use of CBCT in dentistry and head and neck imaging has become widespread. CBCT is preferred for use in osseous structures due to its high diagnostic quality, and low radiation [36]. Also in previous studies, it has been stated that it is effective in examining the neurovascular structures within the maxilla [37]. A review by Centelles et al. [38] emphasizes that CBCT offers superior sensitivity and cost-effectiveness compared to conventional CT for the detection of the PSAC and is recommended as a dose-sparing alternative for maxillofacial imaging. Furthermore, the average arterial diameter reported by CT was significantly larger than that observed in CBCT studies [38]. Therefore, CBCT was used to examine the PSAC anatomy in the present study. In studies evaluating CT images of patients without CLP, PSAC was detected at a rate of 52-64.5% [20, 32, 33, 39]. In studies where CBCT images of patients without CLP were evaluated, the rate was found to be 80.3–98.9% [22, 35, 38, 40, 41]. In a study that analyzed CBCT images of patients with CLP, the PSAC was identified in 100% of the cases [17]. Tannishtha et al. [24] reported that the PSAC was identified in 100% of both CLP and non-cleft cases using CBCT imaging. Similarly, in the current study, PSAC was detected in 100% of the CS and NC of CLP patients. In the present study, 0.4 mm slices were used to examine neurovascular structures.

In the present study, to determine the location of PSAC, the maxillary sinus was divided into 3 regions: superior, middle and inferior. Studies conducted on non-cleft individuals have shown that PSAC is more common in the middle and inferior thirds of the maxillary sinus [23, 42]. Similar to the previous studies, in NC, PSAC in the maxillary sinus is located in the middle and inferior thirds. Gittins et al. [17] reported that the PSAC location in CLP patients was identified more frequently in the middle and superior regions compared to non-cleft individuals. In the present study, the location of PSAC was found in the middle and superior third in CS as well. Similarly, Tannishtha et al. [24], found that the PSAC was located in the middle region in CLP patients, while it was observed in the lower third in the non-cleft individuals, in a study comparing CLP patients with non-cleft patients. Notably, the study conducted by Tannishtha et al. [24] consisted of pediatric patients, and their CLP group included both bilateral and unilateral cases. Our findings align with the existing literature; however, the presented study specifically compared the CS and NC of unilateral cases. There are no similar studies in the literature, limiting the ability to directly compare the findings. The localization of the PSAC in the middle and superior thirds of the maxillary sinus could be associated with the reduced sinus volume and dimensions reported in CLP patients [9, 43, 44]. However, the underlying causes of these maxillary changes in CLP patients remain unclear in the literature. It has been suggested that these differences might be attributed to altered embryological development, nutritional challenges, and transformed airflow dynamics through the nose and sinuses in CLP patients [45, 46]. The proximity of the PSAC to the sinus floor holds clinical significance in sinus lifting surgeries, as it directly impacts the risk of bleeding and surgical visibility, influencing both safety and efficiency of the procedure [47].

In the present study, the entry point of PSAC to the maxillary sinus was evaluated in relation to the teeth. It was observed that the entry point of PSAC moved towards the anterior in CS. In a previous study, no statistical difference was observed between the posterior width and height of the maxilla on the cleft and non-cleft sides in patients with unilateral CLP. However, the anteroposterior length, anterior width, and volume values of the maxilla were found to be significantly lower on the cleft side. This was explained by the cleft being located in the anterior part of the maxilla [44]. At the same time, soft tissue factors such as scarring, muscle pull, and tension in the soft tissue are also involved in the increase in the severity of maxillary hypoplasia in CLP patients. These soft tissue factors have a negative effect on bone growth around the cleft [48, 49]. The authors suggest that since maxillary hypoplasia and anteroposterior length of the maxilla was decreased, the entry point of PSAC could be moved towards anterior direction in CS. According to the study by Hur et al. [50], the relationship between the intraosseous branch of the PSAA and the maxillary sinus floor shows limited variation in height, although the minimal height increases from the first molar region to the first premolar region. Therefore, they suggest that more precautions must be taken in the first molar region compared to the first premolar region during surgical procedures. However, in the presented study, the significant anterior position of the PSAA entry observed in the CS suggests that additional attention should also be given to the premolar region in CS.

Understanding the diameter of an artery is essential to assess the risk of excessive bleeding. Complications become more complex to manage and can be potentially worrisome in larger diameter arteries [51]. In this study, upon evaluating the supero-inferior diameter of the PSAC, it was found that the CS demonstrated significantly larger diameters than the NC. In the study conducted by Gittins et al. [17], the PSAC diameter was found to be larger in CLP patients compared to non-cleft individuals, and it was also significantly larger on the cleft side than on the non-cleft side in unilateral CLP patients. Similarly, Tannishtha et al. [24], reported that the PSAC diameter in cleft patients was found larger than that of non-cleft individuals in their research on a pediatric cohort. Radmand et al. [47] noted that a PSAC diameter exceeding 2 mm could be associated with life-threatening hemorrhages. In the present study, the average supero-inferior diameter on the CS was 1.08 ± 0.2 mm, which is not considered clinically significant in terms of bleeding risk. Experienced clinicians will be able to control blood loss during operations by the limited diameter of the injured PSAC and reactive vasoconstriction. However, this bleeding will compromise the field of vision of less experienced clinicians, resulting in increased blood loss and increased operation time. Based on these results, modification of the osteotomy line should be considered before the planned Lefort 1 surgery in CLP patients due to the different location and large diameters of PSAC. These differences should be taken into account in mini-screw planning that can be applied during orthodontic treatment of CLP patients to avoid bleeding and neurosensory complications due to PSAC injury. In addition, modification of the incision line should be considered in the Caldwell-Luc technique in order not to interrupt the path of the PSAC.

This study has certain limitations, including a small sample size and younger individuals. Furthermore, although there are only a few studies in the literature that evaluated PSAC using CBCT in CLP patients [17, 24], both studies were conducted on CLP and non-cleft patients, and the authors were unable to directly compare their findings. Another limitation is that the authors lacked the clinical information and the surgical history of CLP patients. Also, further studies comparing the non-cleft individuals with unilateral CLP patients may provide a clearer understanding of how CLP specifically affects PSAC anatomy compared to the general population. Further research is required with more sample size and in different age groups for greater and in depth understanding of PSAC in individuals with CLP.

Conclusion

In CS, PSAC location was common in the superior and middle thirds of the maxillary sinus. It was observed that the entrance of PSAC to the maxillary sinus shifted anteriorly in CS. PSAC had larger supero-inferior diameters in CS. Also, during surgery in CLP patients, the PSAC may be positioned more superiorly in the CS compared to the NC. Awareness of its larger diameter can help surgeons anticipate potential complications, such as bleeding and neurosensory damage, and take appropriate precautions. Clinicians should have adequate knowledge about the anatomy of PSAC of CLP patients. CBCT is a useful diagnostic tool for the evaluation of these structures. The treatment of CLP patients is a long and complicated process. During this process, a wide variety of surgical interventions involving the maxilla can be planned. Therefore, future studies should investigate how differences in PSAC anatomy may affect the long-term treatment of CLP patients.

Abbreviations

CBCT Cone-Beam Computed Tomography
CLP Cleft Lip and Palate
CS Cleft side
CT Computed Tomography
NC Non-Cleft side
PSAA Posterior Superior Alveolar Artery
PSAC Posterior Superior Alveolar Canal
SPSS Statistical Package for social sciences

Acknowledgements

Not applicable.

Author contributions

Study Idea / Hypothesis: H.N.A., D.S.C. Study Design: H.N.A., D.S.C., B.T.U., A.C. Data Collection: D.S.C., B.T.U. Literature Review: H.N.A., D.S.C., B.T.U., A.C. Analysis and/or Interpretation of Results: H.N.A., D.S.C. Article Writing: H.N.A., D.S.C., B.T.U., A.C. All authors read and approved the final manuscript.

Funding statement

The present study was supported by the Çukurova University Scientific Research Fund (Project no: TSA-2021-14393).

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. For privacy reasons, however, individual data allowing for the identification of participants cannot be made available.

Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Çukurova University (2021/116 – 69). Written informed consent was obtained from the participant's parents for the present study.

Competing interests

The authors declare no competing interests.

Conflict of interest

The authors declare that they have no conflict of interest.

Received: 18 December 2024 / Accepted: 27 March 2025
Published online: 11 April 2025

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