# Prevalence and Morphological Characteristics of Canalis Sinuosus in Unilateral and Bilateral Cleft Lip and Palate Patients and Normal Controls

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**Objective:** *To compare the prevalence and morphological characteristics of canalis sinuosus (CS) between unilateral cleft lip and palate (UCLP), bilateral cleft lip and palate (BCLP) and control groups.*

**Methods:** *The sample consisted of 238 CBCT images (476 sides) from 98 UCLP subjects (196 sides), 36 BCLP subjects (72 sides) and 104 healthy controls (208 sides). Recorded parameters included prevalence of CS, diameter, location of the teeth and adjacent structures. Afterwards, the recorded parameters were compared between the UCLP, BCLP and control groups.*

**Results:** *The prevalence of CS in the control, UCLP and BCLP groups showed significant differences. The BCLP group revealed a significantly lower prevalence of CS than the UCLP and control groups. There was a considerable increase in CS diameter in the CLP groups compared with the control group. The terminal location of CS was in the canine region for the CLP groups and in the lateral incisor region for the control group. CLP had a significant impact on the location of the end of the CS. CEJB (cementoenamel junction buccal) and CEJL (cementoenamel junction lingual) measurements showed significant differences between the CLP cases and control groups.*

**Conclusion:** *Different characteristics was revealed between the control, UCLP and BCLP groups. Assessment of CS in patients with CLP with CBCT images is crucial before performing surgical procedures.*

**Keywords:** *canalis sinuosus, CBCT imaging, cleft lip and palate*

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Canalis sinuosus (CS) was first characterised in 1939 and named because of its double-curved direction.[1,2] This anatomical structure has neurovascular bundles of anterior superior alveolar nerves and vessels. CS appears from the posterior part of the infraorbital foramen, moves down to the floor of the orbital cavity and reaches the anterior part of the maxilla, also referred to as the premaxilla, and innervates the incisor and canine areas.[1,3-6] Surgical procedures often involve manipulation of this location,[6] for example through insertion of dental implants, orthognathic surgery, impacted tooth surgery, endodontic and periodontal surgical procedures and cyst removal.[7] Failure of surgical procedures in the premaxillary area where the CS is located may lead to bleeding, hyperesthesia, paraesthesia and aching. These complications can go unnoticed among clinicians unless they confront them. It is crucial to identify CS because of the surprisingly high occurrence of this structure, especially in order to avoid iatrogenesis within the premaxilla.[8-11]

Cleft lip and palate (CLP) is a frequent congenital craniofacial deformity that is anticipated to occur in one in every 700 births. It results from a loss of fusion of the frontonasal and maxillary processes and affects surgical procedures close to the CS region including orthognathic surgery (Le Fort I osteotomy), alveolar

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bone grafts and dental implant placement in these individuals.[6,12,13]

Two-dimensional (2D) images, which are normally used, are inadequate to assess CS because of the low quality of images, superimpositions, distortions and magnifications.[2,8] Consequently, CBCT, as a 3D assessment, is considered the maximally informative radiographic approach for performing complete evaluation of the maxillary anatomy before and after surgical procedures.[8,14-17]

CS has been inadequately defined in the literature. Many anatomy textbooks do not contain any precise information about CS and its variations.[8,9] Professionals need to recognise the course and dimensions of the CS so they can prevent the complications that occur during dental procedures in relation to it.[16] In patients with CLP, the premaxilla is changed by the malformation and bone and blood supply are decreased in this region. On the other hand, numerous rehabilitation surgeries are performed in this region.[16] To the best of the present authors' knowledge, few studies have compared the prevalence and characteristics of CS in individuals with CLP using CBCT images. Consequently, this study aimed to compare the prevalence and morphological features of CS between the control group and the CLP group using CBCT images.

## Subjects and methods

The Ethics Committee of Shiraz University of Medical Sciences, Shiraz, Iran approved this study (IR.SUMS.DENTAL.REC.1401.077). The CBCT images and patient documents consulted in the present study were taken from the archives of a private radiology centre. It is important to note that the CBCT images were not taken for this study specifically; those in the control group were taken for different reasons, including third molar extraction, dental implant surgery and treatment of tooth impaction. The case and control groups were chosen at random, conforming to inclusion and exclusion criteria. The inclusion criteria were good quality CBCT images with the possibility of CS visualisation in the scanning zone, and the exclusion criteria were images with bone lesions in the premaxilla.

A total of 238 CBCT images were analysed from 104 healthy controls (208 sides), 98 unilateral CLP patients (196 sides), and 36 bilateral CLP patients (72 sides). The mean age of the contributors was 21.3 ± 2.6 years (range 20 to 30 years). The case and control groups were sex and age-matched. All images had the following parameters: scanning time 14 to 18 seconds, field of view 15 × 12 cm, voltage 110kVp, 3mA, voxel size 0.3 mm and exposure time 5 seconds). The images were taken using a NewTom VGi tool (QR-SRL; Verona, Italy). To confirm the consistent orientation of the images with the sagittal plane, patients were asked to stand upright with their head positioned such the Frankfort horizontal plane was parallel to the floor.

All images were analysed using NNT (NewTom Navigation and Treatment) software. Quantitative Radiology (QR) NNT viewer was used for all multiplanar reconstructions of CBCT scans with a slice thickness of 0.5 mm. A dental student (MA) and an oral and maxillofacial radiologist (MP) analysed the CS for every CBCT image. Fifty images were chosen at random and analysed 2 weeks later by the student. To demonstrate the significance of any mistakes in measurements, a Kappa coefficient test computed inter and intra-observer reliability.

CS presence was the first variable in this study (Fig 1), then, the diameter measurement was taken in the maximum visualised diameter of the CS in the axial plane (Fig 2). The distance of the canal from the neighbouring structures was assessed using the methodology set out by Manhães-Júnior et al.[15] Thus, after locating the CS, four measurements were executed as follows (Fig 3):

1. Nasal cavity (NC): the distance between the terminal portion of the CS to the floor of the nasal cavity;
2. Buccal cortical (BC): the distance between the terminal portion of the CS to the bone of the buccal cortex;
3. Cementoenamel junction buccal (CEJB): the distance from the terminal part of the CS to the maximum protuberance aspect of the buccal face;
4. Cementoenamel junction palatal (CEJP): the distance from the terminal part of the CS to the maximum protuberance aspect of the palatal face.

The canal configuration was evaluated within the sagittal plane for all subjects and labelled as vertical, curved or Y-shape. Lastly, the terminal part of the CS in connection to the teeth was considered using the methodology outlined by de Oliveira et al.[18] The sagittal reconstruction was used to assess the emergence location of the CS in eight dental areas: incisors, canines, premolars, molars, and between these teeth.

For data analysis, SPSS software (version 20; IBM, Armonk, NY, USA) was used. To determine the possible significant differences, a Mann-Whitney test was applied to compare age, diameter, the distance from the terminal part of the CS to CEJB, CEJL, BC and NC, and the connection of the terminal part of the CS to the teeth between the case and control group and in three group analyses between UCLP and control, BCLP and

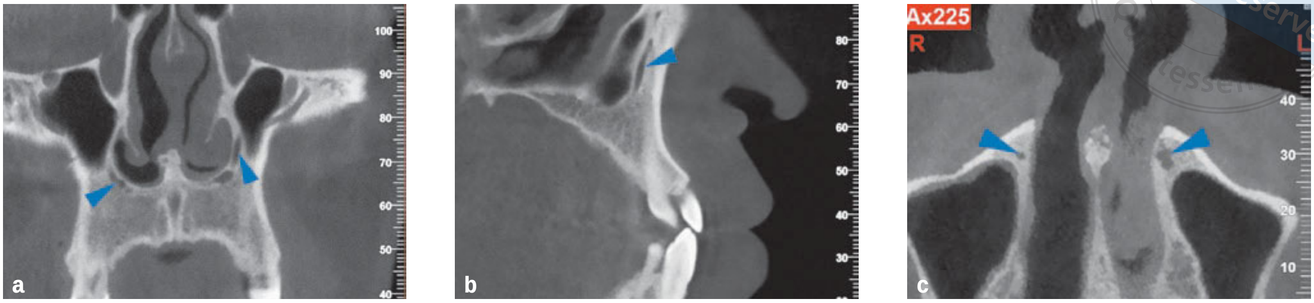


**Fig 1** Coronal **(a)**, sagittal **(b)** and axial reconstruction **(c)** of the CS in CBCT examinations.

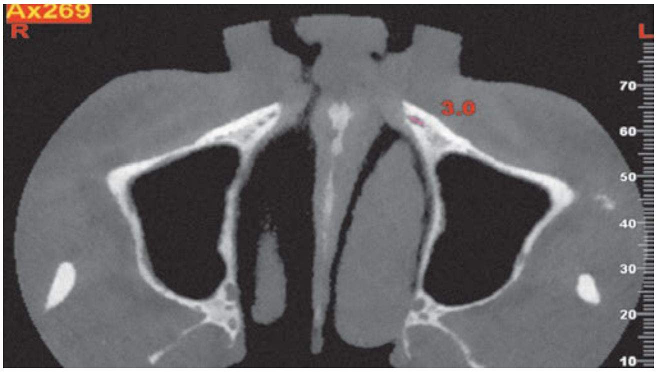


**Fig 2** Measurement of CS diameter on CBCT axial view.

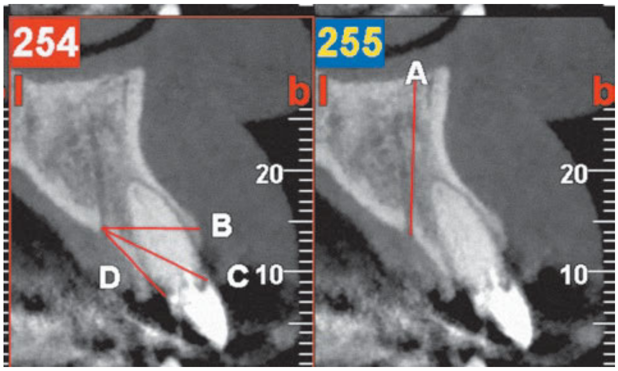


**Fig 3** Distance of the CS to adjacent structures: nasal cavity (A) in cut 255, buccal cortical (B), cementoenamel junction buccal (C), and cementoenamel junction palatal (D) in cut 254. l, lingual; b, buccal.

control and UCLP and BCLP groups. A Wilcoxon signed rank test was used to compare age, diameter and distance of the terminal portion of CS to CEJB, CEJL, BC and NC and the connection of the terminal part of CS to the teeth in the group of UCLP between the sides of cleft and non-cleft. To compare the prevalence and shape of the canal between case and control groups and in three group analyses between UCLP and control, BCLP and control, and UCLP and BCLP groups, a chi-square test was applied. The level of statistical significance was set at $P < 0.05$.

## Results

No statistically meaningful difference was found between the data gathered by the two measurements. The significant reliability of the double measurements was proved because the intraclass correlation coefficient (ICC) of both assessments was > 0.9. Furthermore, the ICC indicated essential concurrence between the two observers.

The CS was detected in 100% of cases bilaterally within the control group and 93.4% in the CLP group. Therefore, a higher prevalence of CS for the control group was observed with a substantial difference ($P = 0.000$). In the three-group analysis, there was a vital statistical difference in the prevalence of CS, with percentages of 100% in the control group, 87.8% in the bilateral group and 95.9% in the unilateral group. No statistically significant difference was found in the prevalence of CS between the aperture and non-cleft side in the UCLP group ($P = 0.18$) (Table 1).

The diameter of CS in the control group was statistically higher than in the UCLP and BCLP groups. No statistical difference was found between the UCLP and BCLP groups regarding the diameter. In the UCLP group, the diameter of the CS was substantially higher on the non-cleft side (Table 2).

Table 3 represents the distance of the canal in connection to the neighbouring structures. NC and BC had no statistical difference between the case and control groups in the three group analyses. No statistical difference was found between the aperture and the non-cleft side in the group of UCLP for NC and BC. CEJB and CEJP had statistical differences between the groups of case and control. In three group analyses, CEJB had

**Table 1** Comparison of prevalence of CS between the groups (chi-square test).

| Group | Prevalence (%) | *P* value |
|---|---|---|
| Control | 100.0 | 0.000 |
| BCLP | 87.8 | |
| UCLP | 95.9 | |
| Affected side | 97.3 | 0.18 |
| Unaffected side | 93.3 | |

**Table 2** Comparison of the diameter of CS between the groups (Mann-Whitney U test and Wilcoxon signed rank test for within-group [cleft vs non-cleft] comparison).

| Group | Mean ± standard deviation, mm | *P* value |
|---|---|---|
| Control | 1.3 ± 0.6 | 0.000 |
| BCLP | 2.4 ± 0.8 | |
| UCLP | 2.3 ± 0.9 | |
| Affected side | 1.5 ± 0.5 | 0.008 |
| Unaffected side | 1.3 ± 0.5 | |

**Table 3** Comparison of the distance of CS emergence to the adjacent structures in CBCT examinations between non-CLP, UCLP and BCLP groups (Mann-Whitney U test and Wilcoxon signed rank test).

| Group | Nasal cavity | | CEJB | | CEJP | | Buccal cortex | |
|---|---|---|---|---|---|---|---|---|
| | Mean ± standard deviation, mm | *P* value | Mean ± standard deviation, mm | *P* value | Mean ± standard deviation, mm | *P* value | Mean ± standard deviation, mm | *P* value |
| Control | 4.9 ± 4.3 | 0.84 | 20.2 ± 6.7 | 0.000 | 21.2 ± 17.6 | 0.000 | 4.6 ± 5.4 | 0.000 |
| BCLP | 6.3 ± 8.1 | | 17.7 ± 9.6 | | 19.3 ± 9.0 | | 6.3 ± 8.1 | |
| UCLP | 5.1 ± 4.5 | | 15.6 ± 7.1 | | 17.6 ± 6.1 | | 4.7 ± 5.4 | |
| Affected | 4.5 ± 3.4 | 0.261 | 15.9 ± 5.9 | 0 .359 | 17.4 ± 5.1 | 0.814 | 4.7 ± 4.4 | 0.544 |
| Unaffected | 6.2 ± 6.1 | | 15.3 ± 8.3 | | 17.8 ± 7.5 | | 5.6 ± 7.3 | |

CEJB, cementoenamel junction buccal; CEJP, cementoenamel junction palatal.

**Table 4** Distribution of CS shape in CBCT examinations between non-CLP, UCLP and BCLP groups (chi-square test).

| Group | CS shape (%) | | | *P* value |
|---|---|---|---|---|
| | C | V | Y | |
| Control | 85.6 | 10.5 | 3.8 | 0.318 |
| BCLP | 71.6 | 13.5 | 1.4 | |
| UCLP | 87.1 | 6.2 | 2.1 | |
| Affected side | 85.3 | 8.0 | 2.7 | 0.52 |
| Unaffected side | 84.0 | 6.7 | 2.7 | |

statistical differences between the groups of control and UCLP and between the groups of control and BCLP. CEJP became statistically different between the groups of control and the UCLP in three group analyses and had no statistical difference between the groups of UCLP and BCLP and between the control and the BCLP group. In the group of UCLP, no statistical difference was found between the cleft side and the non-cleft side in CEJB and CEJP.

The terminal part of the CS in connection to the teeth was statistically different between the control group and the UCLP group and between the groups of control and BCLP. No statistical difference was found between UCLP and BCLP groups, and dental region incidence in both was in the canine region. In the group of UCLP, there were no statistical differences between the cleft side and the non-cleft side. The control group had a higher prevalence for the lateral incisor, and the case group for the canine regions.

No statistical differences were found between the case and control groups ($P = 0.13$) and between the cleft and non-cleft sides in the group of UCLP in CS configuration ($P = 0.52$). No statistical difference was found between the three groups (P = 0.318) according to the configuration of the CS (Table 4).

## Discussion

Accurate identification of anatomical structures is essential before performing any surgical procedures to advance prognosis and avoid complications. There is a lack of investigations about CS, and many practitioners are not aware of this anatomical structure. Furthermore, many surgical procedures are performed in the premaxilla. Thus, careful assessment of this region is crucial, especially for patients with CLP, because of rehabilitation or other surgeries they undergo in the CS region.[2,3,13,14,19] This study aimed to evaluate and compare CS and its features between control populations with unilateral and bilateral CLP groups.

The prevalence of CS was considerably higher in the control group than in the UCLP and BCLP groups, and higher in the UCLP group than the BCLP group. A possible explanation for this result may be the fact that CLP leads to a lack of fusion of the maxillary process and the absence of bone in the CS region, which makes it difficult to visualise the canal.[16]

The prevalence of CS in the CLP group was 93.7%, similar to the value reported by Ferlin et al[13] who found that the prevalence of CS was 98.5% on the left side and 98% on the right side in the CLP group, lower than the controls (100% bilaterally).

Previous studies showed a wide range between 34.86% and 100% for prevalence of CS in patients without CLP.[4,13-16,19,20] CS was present in 100% of control group subjects bilaterally in the present study. Significant differences in prevalence observed in different studies may also be due to technical differences (other exposure parameters, voxel size, CBCT scanners, inclusion/exclusion criteria, etc.) or distribution of study groups, or may be accidental.[2]

The importance of canal diameter is related to the danger of bleeding and other complications in different surgeries.[8,13,19] CS diameter in the normal controls was statistically lower than in the groups of UCLP and BCLP. In the UCLP group, CS diameter was statistically higher on the cleft side than on the non-cleft side. Similar to the present results, Ferlin et al[13] also found that CS diameter in CLP patients was higher than in the controls, and was higher on the cleft side than the non-cleft side in UCLP patients. This may be because of the changes in the result of different surgeries for rehabilitation, which alter the typical growth pattern of the maxillary region.[13] Amin et al[21] studied embryonic development in mice with CLP. They assessed large dimensions of the nasopalatine canal, which may result from compensation for the fewer neurovascular bundles in the sites affected by CLP.

Previous studies verified the location of CS.[9,11,19,22] The distance from the canal to the neighbouring structures remained the same as that reported by Manhães-Júnior et al[15] for NC and BC; however, the latter study also used the crest of the ridge in the dental region. The present authors altered this structure with the CEJB and CEJP, like Ferlin et al.[13]

CEJB and CEJL in the control group were statistically higher than in the BCLP and UCLP groups. There were no statistically significant differences in NC and BC between the groups. Ferlin et al[13] found that BC was firmly lower in the control group than CLP subjects, and other parameters showed no statistical difference between the case and control group.

The anterior maxilla was identified as the most frequent location for the terminal portion of CS according to previous studies.[3,7,9-11,13,15,16,18-20,23-25] Aoki et al[3] found that the end of the CS was more frequently found in the incisor region. Ferlin et al[23], in a systemic review, mentioned that the anterior maxilla was the most frequent region for CS. The present authors found that the end of the CS was near lateral incisors in the control group, which aligns with previous studies that reported that CS was more frequent in the anterior maxilla. Ferlin et al[13] reported that accessory canals to the CS were located near molars and premolars in the CLP group. In contrast with Ferlin et al,[13] the present authors found the CS end portion in the CLP group was near canines. It seems that the malformation in the premaxilla in CLP patients does not cause the CS to divert its trajectory.

The present authors found that the percentage of curved CS courses was higher in all groups. A study by von Arx et al[25] on populations without CLP showed that CS with a curved shape was the most prevalent.[6] Tomrukçu et al[2] reported that the curved-shape configuration of CS was the most frequent CS morphology. Thus, the present results were in line with Tomrukçu et al[2] and von Arx et al[25] with regard to CS configuration. There were no statistical differences between all groups regarding CS shape in the present study, and CLP did not affect CS shape.

2D images have some limitations, such as superimposition, magnification, distortion and low quality, and are insufficient to diagnose CS. CBCT is the best method of radiography to assess the anatomical structures in the maxillary region and has gained widespread acceptance in dentistry to prevent possible failures. This method makes it possible to investigate CS in three dimensions: axial, coronal and sagittal. Thus, surgeons can receive precise information about the bony anatomical structures. This technique is lower cost, has a lower radiation dose and has the highest spatial resolution. CBCT also significantly decreases the image overlap, has a small voxel size, permits the reconstruction of multiplanar images and allows different measurements.[9,15,17,20,23] Studies reveal that surgeons must evaluate the surgical site through CBCT before conducting surgery.[13] Thus, CBCT images were used in the present study.

This study has several limitations that should be considered. First, the number of participants in the BCLP group was relatively small compared to the UCLP and control groups, which may have reduced the statistical power of subgroup analyses. Second, all CBCT images were obtained from a single radiology centre, which may limit the generalisability of the findings to other populations or imaging protocols. Third, the study population was limited to individuals aged 20 to 30 years, excluding paediatric and elderly populations where anatomical variations of the CS might differ.

## Conclusion

The present investigatio showed different characteristics between the control, UCLP and BCLP groups. CS diameter differed in the CLP group compared to the average population, and localisation of CS differed between the CLP group and control group. It is therefore essential to evaluate this anatomical structure in CLP patients on CBCT images before performing surgery.

## Conflicts of interest

The authors declare no conflicts of interest related to this study.

## Author contribution

Both authors contributed to the data collection, analysis and manuscript draft and revision.

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