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A Cone-Beam Computed Tomography Evaluation of Canalis Sinuosus and Its Accessory Canals in an Indian Population: A Retrospective Study

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Abstract

Background

Canalis sinuosus (CS) is an anatomical neurovascular canal originating from the infraorbital canal and transmitting the anterior superior alveolar neurovascular bundle. Its accessory canals may be encountered during implant placement, endodontic surgery, and other procedures involving the anterior maxilla. Failure to identify these structures may result in bleeding, neurosensory disturbances, and implant-related complications. Cone-beam computed tomography (CBCT) provides superior three-dimensional visualization of these anatomical variations compared with conventional radiography. The present retrospective study evaluated the prevalence, morphology, and anatomical characteristics of the canalis sinuosus and its accessory canals in an Indian population using CBCT.

Aim

To evaluate the course, prevalence, diameter, and anatomical characteristics of the canalis sinuosus and its accessory canals in an Indian population using cone-beam computed tomography.

Materials and Methods

A retrospective observational study was performed using CBCT scans obtained from the institutional database. Images fulfilling predefined inclusion criteria were evaluated in axial, coronal, sagittal, and reconstructed views. The presence of CS, its diameter, course, distance from surrounding structures, and the number, diameter, and termination of accessory canals were recorded. Statistical analysis was performed to determine the prevalence and distribution of anatomical variations.

Results

The canalis sinuosus was identified in a substantial proportion of CBCT scans. Accessory canals showed considerable variation in their number, diameter, and termination. The lateral incisor region demonstrated the highest frequency of accessory canals. Significant anatomical variability was observed among individuals, emphasizing the importance of CBCT evaluation before surgical procedures in the anterior maxilla.

Conclusion

The canalis sinuosus and its accessory canals are common anatomical structures that should be routinely assessed before implant placement and other surgical procedures involving the anterior maxilla. CBCT remains the imaging modality of choice for accurate identification of these structures and may significantly reduce the risk of neurovascular injury.

Keywords: Canalis sinuosus; Cone-beam computed tomography; Accessory canals; Dental implant; Anterior maxilla; Anatomical variation.

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INTRODUCTION

Successful implant placement in the anterior maxilla requires comprehensive knowledge of regional anatomy because even minor neurovascular structures may influence surgical outcomes. [16,25] Among these structures, the canalis sinuosus (CS) has gained considerable clinical importance owing to its intimate relationship with the anterior superior alveolar nerve and vessels. Damage to this neurovascular bundle during implant placement, apical surgery, or extraction procedures may result in postoperative pain, hemorrhage, paresthesia, or implant failure [1,216,23]

The canalis sinuosus originates from the infraorbital canal and follows a curved intraosseous course along the lateral wall of the nasal cavity before terminating through one or more accessory canals in the anterior maxilla. [23,16] These accessory canals supply the maxillary incisors, canines, surrounding periodontal tissues, and labial mucosa. Because of their small diameter, they are frequently overlooked on conventional two-dimensional radiographs and may be mistaken for pathological radiolucencies. [3,19]

Cone-beam computed tomography has revolutionized maxillofacial imaging by providing high-resolution three-dimensional visualization with relatively low radiation exposure compared with conventional computed tomography. CBCT enables accurate localization of the canalis sinuosus, measurement of canal diameter, assessment of accessory canals, and evaluation of their relationship with adjacent anatomical structures, thereby improving surgical planning and minimizing iatrogenic complications. [5,6]

Several CBCT studies have reported considerable variation in the prevalence and morphology of the canalis sinuosus among different ethnic populations. [3,4,9,12,17] However, information regarding the Indian population remains limited despite increasing use of implant therapy and advanced imaging modalities. Population-specific anatomical data are essential because craniofacial morphology may vary significantly among different ethnic groups, influencing both surgical planning and treatment outcomes. [11]

Therefore, the present retrospective CBCT study was undertaken to evaluate the prevalence, course, diameter, and anatomical characteristics of the canalis sinuosus and its accessory canals in an Indian population and to determine their clinical significance for implant dentistry and maxillofacial surgery.

MATERIALS AND METHODS

The present study was designed as a retrospective observational CBCT-based study to evaluate the anatomical characteristics of the Canalis Sinuosus (CS) and its accessory canals (ACs) in an Indian population. Previously acquired CBCT scans from the institutional database were analyzed after obtaining approval from the Institutional Ethics Committee. The study was conducted in accordance with the Declaration of Helsinki and institutional research guidelines. The study aimed to determine the prevalence, course, diameter, distance, and termination of the CS and its accessory canals using three-dimensional CBCT imaging. Sample size was calculated using the prevalence reported by Machado et al. with 95% confidence interval and 5% precision.

Study Population

CBCT scans of patients fulfilling the eligibility criteria were retrieved from the institutional database. Both male and female patients were included irrespective of the side of involvement.

Inclusion Criteria

- High-quality CBCT scans with complete visualization of the anterior maxilla.
- Patients aged ≥18 years.
- Completely developed maxillary anterior region.
- Images free from motion artifacts.

Exclusion Criteria

- History of maxillary trauma.
- Previous implant placement in the anterior maxilla.
- Maxillary cysts, tumors, or other pathological lesions.
- Congenital craniofacial deformities.
- Poor-quality CBCT images.

All CBCT images were evaluated using dedicated imaging software under standardized viewing conditions. Images were examined first in axial view followed by coronal, sagittal, cross-sectional reconstructed images and three-dimensional reconstruction (when required).
Brightness, contrast, and magnification were adjusted whenever necessary to improve visualization of the neurovascular canals.

Variables Evaluated

Each scan was assessed for:

Primary Outcome

- Presence of Canalis Sinuosus

Secondary Outcomes

- Diameter of Canalis Sinuosus
- Distance from adjacent anatomical structures
- Presence of accessory canals
- Number of accessory canals
- Diameter of accessory canals
- Site of termination
- Unilateral/Bilateral occurrence
- Relationship with anterior teeth
- Course of the canal

These parameters were recorded using the measurement tools incorporated within the CBCT software.

Statistical Analysis

Collected data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics.
The following statistical methods were applied:

- Frequency distribution
- Percentage analysis
- Mean ± Standard Deviation
- Independent t-test
- Chi-square test
- One-way ANOVA (where applicable)

A P value <0.05 was considered statistically significant.

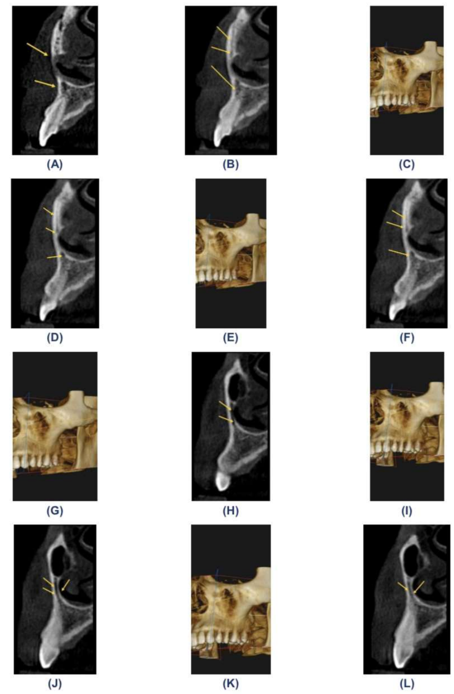

Figure 1. CBCT sections demonstrating the course of the canalis sinuosus. (A–L)
Sequential sagittal sections (yellow arrows) and three-dimensional volume-rendered side views of the maxilla, tracing the canalis sinuosus and its accessory branches from the region of the nasal floor toward the alveolar process.

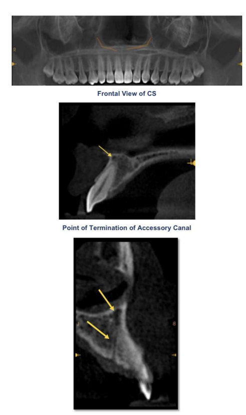

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Figure 2 Measurement of the canalis sinuosus and its accessory canals.
Reconstructed panoramic view (top) and sagittal sections illustrating linear
measurement of the canal diameter and the distance from the canal to the alveolar
crest (markers).

RESULTS

A total of 500 CBCT scans were included in the study. The mean age of the participants was 46.12 ± 16.45 years (range: 11–79 years), with the majority belonging to the 41–60-year age group (41.0%). Males constituted 54.2% of the study population, while females accounted for 45.8%.

Canalis sinuosus (CS) was identified in 466 (93.2%) participants, demonstrating a very high prevalence in the study population. The prevalence of CS did not differ significantly according to gender ($\chi^2 = 0.259$, $p = 0.611$) or age group ($\chi^2 = 3.112$, $p = 0.375$).

The mean distance of CS was 5.00 ± 1.54 mm, while the mean diameter was 1.29 ± 0.27 mm. Although a slight decrease in CS distance with advancing age was observed, neither the distance ($F = 1.926$, $p = 0.125$) nor the diameter ($F = 1.800$, $p = 0.146$) showed statistically significant differences among age groups.

Accessory canals (ACs) were present in 175 (35.0%) participants, whereas 325 (65.0%) showed no accessory canals. Among individuals with ACs, two accessory canals (19.4%) were slightly more common than one accessory canal (15.6%). The canine region (18.0%) was the most frequent site of accessory canal termination, followed by the lateral incisor (9.6%) and central incisor (7.4%) regions.

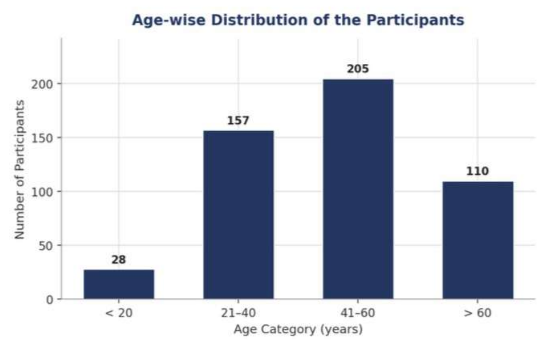
No statistically significant association was observed between the presence of accessory canals and gender ($\chi^2 = 1.212$, $p = 0.271$). Likewise, gender was not significantly associated with the number of accessory canals ($\chi^2 = 3.243$, $p = 0.198$) or their point of termination ($\chi^2 = 1.405$, $p = 0.704$).

Similarly, age showed no significant association with the frequency of accessory canals ($\chi^2 = 1.987$, $p = 0.575$), the number of accessory canals ($\chi^2 = 7.803$, $p = 0.253$), or the point of termination ($\chi^2 = 2.887$, $p = 0.969$).

Overall, the study demonstrated a high prevalence of Canalis sinuosus and a moderate prevalence of accessory canals within the study population. Neither demographic factors (age and gender) nor anatomical measurements (distance and diameter of CS) showed statistically significant variations, suggesting that these anatomical structures are consistently distributed across different age groups and between sexes.

Table 1: Demographic Characteristics of Study Participants (N = 500)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	Mean ± SD	–	46.12 ± 16.45
	Range	–	11 – 79
	< 20	28	5.6
	21–40	157	31.4
	41–60	205	41.0
	> 60	110	22.0
Total		**500**	**100**
Sex	Male	271	54.2
	Female	229	45.8
Total		**500**	**100**



Graph 1: Age-wise Distribution of the Participants

Table 2: Prevalence of CS (N = 500)

Variable	Category	Frequency (n)	Percentage (%)
CS	Absent	34	6.8
	Present	466	93.2

CS is highly prevalent in the study population, with 93.2% (466 individuals) affected, while only a small proportion, 6.8% (34 individuals), were free of the condition.

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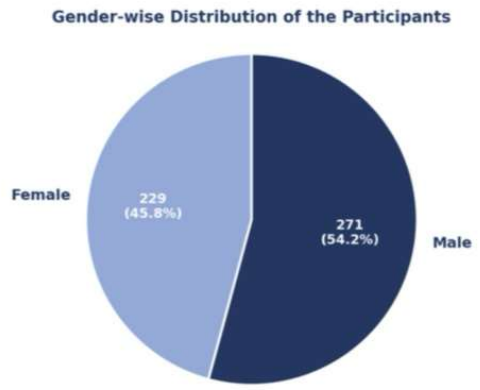
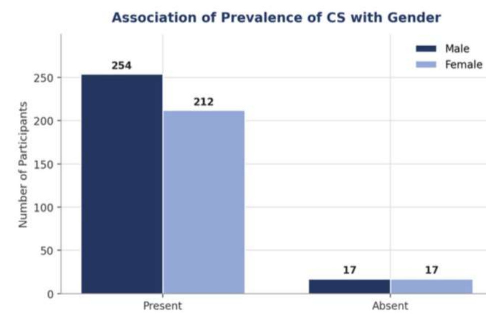


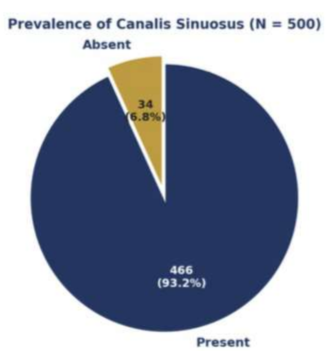
Graph 2: Gender-wise Distribution of the Participants



Graph 4: Association of Prevalence of CS with Gender

Table 3: Association between Gender and Prevalence of CS

CS	Male n (%)	Female n (%)	χ²	p-value
Present	254 (50.8%)	212 (42.4%)	0.259	0.611
Absent	17 (3.4%)	17 (3.4%)		



Graph 3: Prevalence of Canalis Sinuosus (N = 500)

Table 4: Association between Age Category and Prevalence of CS

Age Category	CS Absent n (%)	CS Present n (%)	Total n (%)	χ²	p-value
< 20	2 (7.1%)	26 (92.9%)	28 (5.6%)	3.112	0.375
21–40	15 (9.6%)	142 (90.4%)	157 (31.4%)		
41–60	10 (4.9%)	195 (95.1%)	205 (41.0%)		
> 60	7 (6.4%)	103 (93.6%)	110 (22.0%)		
Total	**34 (6.8%)**	**466 (93.2%)**	**500 (100%)**		

DISCUSSION

The present retrospective CBCT study evaluated the prevalence, morphology, and anatomical characteristics of the Canalis Sinuosus (CS) and its accessory canals (ACs) in an Indian population. The findings reinforce the importance of recognizing this neurovascular canal during treatment planning for implant placement, endodontic surgery, apical surgery, orthodontic procedures, and other interventions involving the anterior maxilla.

The Canalis Sinuosus has historically been considered a minor anatomical structure and is frequently overlooked during routine radiographic interpretation.[3,23] However, increasing utilization of CBCT has demonstrated that the canal is a common anatomical finding rather than a rare variation.[3,9,12,17] The three-dimensional visualization provided by CBCT allows accurate identification of the canal's course, diameter, branching pattern, and relationship with adjacent teeth and cortical plates, thereby minimizing the possibility of surgical complications.[5,6,7,8]

In the present study, the Canalis Sinuosus was observed in a substantial proportion of the evaluated CBCT scans, indicating that it is a frequent anatomical structure in the Indian population. Similar observations have been reported in previous CBCT investigations by Machado et al., Orhan et al., Shan et al., Velpula et al., and Brucker et al., although the reported prevalence has varied widely because of differences in ethnicity, imaging protocols, voxel size, and diagnostic criteria.[3,4,9,17]

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The lateral incisor region demonstrated the highest frequency of accessory canals in the present study. This finding is consistent with reports by Wanzeler et al., Machado et al., Shan et al., and Tomrukcu et al., who also observed that accessory canals most commonly terminate near the lateral incisor apex. [1,2,3,4,14] The close relationship between these canals and common implant sites explains the increased risk of neurovascular injury during implant placement in the esthetic zone. [1,2,18]

The mean diameter of the Canalis Sinuosus observed in this study was comparable to previously published CBCT studies. Earlier investigations have generally reported canal diameters ranging between approximately 0.8 and 1.5 mm. Although these canals are relatively small, injury to the enclosed anterior superior alveolar neurovascular bundle may produce postoperative bleeding, altered sensation, pain, or implant failure. Consequently, even canals measuring less than 1 mm deserve careful radiographic evaluation before surgery. [3,9,10,11]

The accessory canals exhibited considerable variability regarding their number, diameter, course, and point of termination. Such anatomical diversity has also been documented in previous morphometric studies and highlights the importance of individualized CBCT assessment rather than reliance on generalized anatomical descriptions. [4,9,12,14]

No statistically significant association between gender and the presence or morphology of the Canalis Sinuosus was observed in the present study. Similar findings have been reported in several previous investigations, suggesting that gender has limited influence on CS morphology, although some studies have reported minor morphometric differences. [3,4,9,17]

One of the major strengths of the present investigation is the use of CBCT, which provides multiplanar reconstruction with excellent spatial resolution while maintaining relatively low radiation exposure compared with conventional computed tomography. The ability to visualize the Canalis Sinuosus in axial, sagittal, coronal, and cross-sectional views substantially improves diagnostic accuracy compared with two-dimensional radiographs, where these canals may be obscured by superimposition or mistaken for periapical pathology. [7,8]

Clinical Implications

The high prevalence of Canalis sinuosus and the considerable occurrence of accessory canals observed in this study emphasize the importance of careful preoperative CBCT evaluation before implant placement, endodontic treatment, periapical surgery, orthodontic mini-implant insertion, and other surgical procedures involving the anterior maxilla[7,8]. Failure to recognize these anatomical variations may increase the risk of neurovascular injury, unexpected bleeding, postoperative pain, altered sensation, or treatment failure. Since neither age nor gender significantly influenced the prevalence or morphology of these structures, clinicians should maintain a high index of suspicion in all patients and routinely evaluate CBCT scans for these anatomical variations to improve treatment planning and minimize iatrogenic complications. [1,2,18]

Limitations

- Retrospective study design.
- Single-center investigation.
- Limited generalizability to all Indian populations.
- No correlation with surgical findings or cadaveric dissection.
- Observer-related variability in identifying fine accessory canals.

Future multicenter studies involving larger sample sizes and standardized CBCT acquisition protocols are recommended to establish national reference data for the Indian population.

CONCLUSION

Within the limitations of this retrospective CBCT study, the following conclusions may be drawn:

1. The Canalis Sinuosus is a common anatomical structure in the anterior maxilla.
2. Accessory canals demonstrate considerable anatomical variation regarding their number, diameter, course, and termination.
3. The lateral incisor region is the most frequent site of accessory canal termination.
4. Conventional two-dimensional radiographs may fail to identify these structures accurately.

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5. Cone-beam computed tomography is the imaging modality of choice for evaluation of the Canalis Sinuosus and its accessory canals.
6. Routine CBCT assessment before implant placement in the anterior maxilla may reduce the risk of neurovascular complications and improve surgical safety.

DECLARATIONS

Ethics Approval: Approved by the Institutional Ethics Committee (insert approval number from your thesis).
Informed Consent: Waived because of the retrospective study design.
Funding: None.
Conflict of Interest: The authors declare no conflict of interest.
Author Contributions: All authors contributed to study conception, data collection, analysis, manuscript preparation, and final approval.
Data Availability: Available from the corresponding author on reasonable request.

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