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Prevalence and Anatomical Importance of the Canalis Sinuosus in an Iranian Population Using CBCT Imaging

Solmaz Valizadeh[a], Mitra Ghazizadeh Ahsaie[a], Hadis Ahmadvand[b]*

[a]Department of Oral and Maxillofacial Radiology, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[b]Dentist, Dental Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
***Correspondence to Hadis ahmadvand, Email: Hadisahmadvand890@yahoo.com**

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Abstract

Objective(s): Canalis sinuosus (CS) is a neurovascular canal in the anterior maxilla that contains branches of the Anterior Superior Alveolar (ASA) arteries and nerves. The aim of this study was to introduce this important anatomical landmark and investigate its prevalence in Cone Beam Computed Tomography (CBCT) images in a sample of Iranian population. **Methods:** In this study, using Ondemand software, 580 CBCT images of the maxilla were analyzed. The presence of the CS in axial, coronal, and sagittal sections was evaluated using four anatomical criteria and its prevalence was calculated. The reliability assessment of qualitative variables was performed using the Kappa agreement coefficient. At the patient level, the distribution of qualitative variables was compared using the Chi-Square test. Analyses were performed at $p<0.05$. **Results:** In this study, the prevalence of the CS canal was estimated to be 37.8%, which was found to be significantly higher in males than in females ($P = 0.002$). **Conclusion:** This study showed that the CS canal has a relatively high prevalence in Iranian population. Therefore, in order to prevent possible surgical complications in the anterior maxillary area, it is recommended that the anatomical location of the canal be reported in CBCT images of patients, and appropriate treatment planning decisions be made by clinicians accordingly.

Keywords: Canalis Sinuosus; Cone Beam Computed Tomography; Anterior Maxilla

Introduction

Canalis sinuosus (CS) is a neurovascular canal that accommodates branches of the Anterior Superior Alveolar (ASA) arteries and nerves [1,2]. Some authors name the terminal part of the CS canal that reaches the maxillary alveolar process differently; including: continuation of the CS canal, subsidiary canals of the CS canal, sinuous canaliculus, anterior superior alveolar canal, neurovascular variation in the anterior palate, or lateral Incisive canal[3-8].Recent Systematic Review studies have shown that the terminal part of the CS canal is more commonly located in the anterior maxilla, especially in the incisor and canine areas [2,9]. Its path through the alveolar process makes it susceptible to damage during surgeries such as dental implant placement [10]. Previous studies also indicate that the CS canal can show various anatomical variations regarding its diameter, bifurcation, length, and pathway. The maxillary bone in the superior-anterior area of the CS canal is very thin, making the Anterior Superior Alveolar Nerve (ASAN) prone to damage [4].
According to the PubMed database, the CS canal has only gained attention in the past five years. Considering the very few articles about the anatomical variations of the CS canal and the fact that these variations are usually incidentally seen in CBCT images, many clinicians are unaware of its presence, location, and clinical importance [5,11]. To the extent that sometimes the CS canal may even be mistakenly diagnosed as a periapical infectious disease or a lesion [6], or it may mimic a lesion due to its proximity to the roots of anterior teeth, which can cause confusion in diagnosis. Shah et al reported a case where a subsidiary branch of the CS canal was mistakenly diagnosed as an external root resorption on a periapical radiograph [7].
Various surgeries in the anterior maxillary area including the maxillary sinus surgery, removal of the impacted canine, placement of implants for orthodontic anchorage[12], orthognathic surgery, and more importantly, placement of dental implants are challenging due to biomechanical, phonetic, and aesthetic demands [13]. Numerous reports exist regarding the surgical complications caused by potential CS canal damage, such as severe bleeding during the surgical procedure in the anterior maxilla with an unknown cause, unexplained pain associated with implant placement in the anterior maxilla [14], midface pain associated with ASAN nerve damage, temporary or permanent neurosensory disturbances such as paresthesia, possible lack of osseointegration, and local infection in the anterior maxilla[15]. Placement of dental implants in the anterior maxilla, considered the first choice for replacing edentulous areas, is a complex challenge requiring precise pre-surgical planning [16,17]. Although sensory disturbances resolve after implant removal in most patients, some experience permanent sensory disturbance even after implant removal [18]. Additionally, it has been noted that re-

implantation in contact with neurovascular bundles can lead to the lack of osseointegration [19].

Regarding the investigation of the CS canal in radiographic images, it should be noted that in the past, these morphological changes were hardly identified due to low-quality images, which could lead to surgical complications due to unknown factors during procedures in the anterior maxilla. Two-dimensional radiographic images have multiple limitations, and due to these limitations, the CS canal is difficult to detect in them; because the diameter of these canals is usually less than 1 mm, and the porous cortical layers and the variable course of the canal also make its detection challenging in 2D radiographs [20]. However, sometimes it is incidentally observed in periapical images or panoramic radiographs showing a large area of the jaws. In two-dimensional images, the extension of the CS canal towards the anterior maxillary teeth, when appearing as a round radiolucency with defined borders, may mimic an inflammatory lesion or root resorption; especially when superimposed on the roots. In panoramic radiographs, the canal path may be interpreted as a developmental cleft or a fracture [21].Currently, the most reliable method for identifying these anatomical variations is the use of CBCT imaging [10]; especially due to the increasing use of dental implants, multiplanar imaging evaluation before surgery is crucial to prevent unforeseen complications [6].

Given the importance of this anatomical structure in surgical procedures in the anterior maxilla, there is a need for studies regarding its characteristics to prevent related surgical complications [5]. The aim of this study was to introduce this anatomical landmark and assess its prevalence in CBCT images of an Iranian population. The results of this study not only increase clinicians' awareness of anatomical variations in the anterior maxilla, but also emphasize the importance of CBCT evaluation before surgery, especially for implant placement in this area [3].

Methods

This observational study was performed in Shahid Beheshti Dental School, Tehran, Iran, betweenAugust 2023 and August 2025, after being approved by the ethics committee of Dental School, Shahid Beheshti University of Medical Sciences. (IR.SBMU.DRC.REC.1401.097). Considering the retrospective nature of the study and the absence of patient information in the final report, there was no specific ethical concern. The CBCT images used in this study, which had previously been taken for various dental problems [8], were extracted from the archive of the Radiology Department of Shahid Beheshti Dental School. No patient was exposed to additional radiation solely for research purposes.

CBCT images of patients were evaluated in which their maxilla was fully covered: from the upper border above the lower rim of the orbit, to the lower border below the surface of the upper alveolar ridge, including the maxillary dental arch. For increasing the validity of results, at the beginning, the presence of the CS landmark was reviewed by the observer in 20 cases and repeated again after two weeks, to determine the Intra-observer reliability. The observer was a dentist under direct supervision of a faculty member specialized in oral and maxillofacial radiology.

Patient images with the following conditions were excluded from the study:

- Patients who had undergone surgical procedures or bone grafts in the anterior maxilla area
- Patients with implants in the anterior maxilla
- Patients with pathological lesions leading to severe bone resorption
- Patients with malformations and anomalies such as cleft palate in the anterior maxilla
- Patients with a history of trauma and fracture
- Presence of screws and plates in the anterior maxilla
- Patients with supernumerary or impacted teeth in the anterior maxilla
- Patients in the mixed dentition period in the anterior maxilla
- Patients whose CBCT images were of unsatisfactory quality due to movement or artifact.

In line with previous studies [3, 6, 13], and considering an estimated prevalence of P = 0.4, a 95% confidence level, and a 4% maximum accepted error, the required sample size was calculated to be 580 using the following formula:

$$n = \frac{Z^2_{1-\frac{\alpha}{2}} \times P \times \left(1-P\right)}{d^2}$$

Strict eligibility criteria were applied to minimize potential confounding factors. To minimize the effect of selection bias, 1200 CBCT scans were assessed for eligibility, and 580 were selected according to the eligibility criteria. CBCT images of the maxilla, under the conditions (FOV=8*8, 8*12, 11 cm, KVP=85-120, Automatic mA, High Resolution, and slice Thickness=0 mm) that had been acquired using NewTom VGi scanner (NewTom, Cefla S.C., Imola, Italy) were evaluated using the Ondemand software to determine the presence of the CS canal.

Initially, in the Ondemand software, in the axial section with a slice thickness of 0 mm, the area between the first right and left premolar teeth of the maxilla, from the lower boundary of the maxillary sinus to the alveolar ridge crest, was reviewed from top to bottom. Any bony canal with the following conditions was considered a possible CS canal. The criteria for identifying a canal as a CS canal were that it simultaneously met the following:

1. The canal had to be corticated, partially corticated, or non-corticated;
2. Any bony canal other than the Nasopalatine canal in the anterior maxilla;

3. Any bony canal that could be identified in all three CBCT sections: axial, sagittal, and coronal;
4. Any bony canal originating from the Infraorbital canal and having a downward path around the anterior wall of the nasal cavity towards the alveolar process.

Any canal that did not meet these conditions and had a different origin was considered a feeding canal [24].

According to the criteria, the canal considered in the axial section had to also be visible in the sagittal and coronal sections to be confirmed as a CS canal. Therefore, after reviewing the axial section, the sagittal section was first reviewed from the left first premolar to the right first premolar from left to right. Then, the coronal section was evaluated from the ANS area to the distal extent of the first right and left premolars from front to back. If the intended canal was visible in all three mentioned sections, it was considered a CS canal. Figures 1, 2 show CBCT image sections with Canalis sinuosus in axial, coronal and sagittal views.

The reliability assessment of qualitative variables was performed using the Kappa agreement coefficient. At the patient level, the distribution of qualitative variables was compared using the Chi-Square test. Analyses were performed at p<0.05.

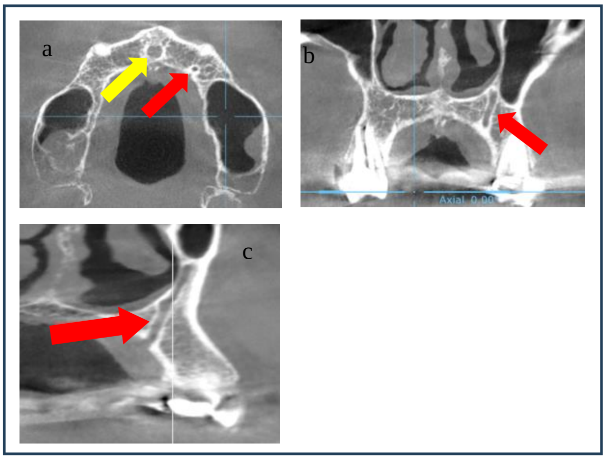

Figure 1: Different CBCT image sections showing Canalis sinuosus in the area of the right maxillary canine.
a) Axial section showing the cross-section of the CS canal.
b) Coronal section showing the pathway of the CS canal in the maxillary bone towards the alveolar process.
c) Sagittal section showing the downward path of the CS canal.
CS canal = red arrow; Nasopalatine canal = yellow arrow.

Figure 2: The pathway of the CS canal in the maxillary bone, clearly visible in the coronal section of the CBCT image.

Results

To ensure the accuracy and consistency in identifying the CS, the observer initially evaluated 20 CBCT scans and repeated the assessment after two weeks. Intra-observer reliability was assessed using the Kappa statistic, which yielded a value of 0.72, indicating substantial agreement. A Kappa coefficient above 0.6 is generally considered acceptable, suggesting good reliability in detecting the presence of the CS canal.

A total of 580 CBCT scans were analyzed, comprising 311 females (53.6%) and 269 males (46.4%). The CS canal was identified in 219 cases (37.8%), with a 95% confidence interval ranging from 34% to 42%.

Table 1- Distribution of CS Canal Prevalence by Gender

Gender	CS Present	CS Absent	Total	Prevalence (%)
Female (N= 311)	99	212	311	31.8%
Male (N= 269)	120	149	269	44.6%
Total (N= 580)	219	361	580	37.8%

Statistical analysis using the Pearson Chi-Square test revealed a significant association between gender and the presence of the CS canal (P = 0.002), with a higher prevalence observed in males. The effect size, calculated as the Odds Ratio, was approximately 1.72, indicating that males were 1.72 times more likely than females to exhibit the CS canal.

Discussion

Knowledge and awareness about anatomical variations are extremely important for surgical treatment planning and post-treatment, as it can prevent complications during surgical procedures and guarantee a better prognosis. Ignoring anatomical variations may cause surgical failure. In most cases, the only anatomical structure considered in the anterior maxillary area is the Incisive Canal; however, there is another structure that may influence surgical success in this region: a variation of the ASAN known as Canalis sinuosus (CS) [25].
Damage to any part of the CS canal's path inevitably leads to issues in the affected area. Despite limited studies, there are several cases showing complications due to the lack of knowledge about the CS canal, especially in dental implant surgeries in the anterior maxilla, such as pain and paresthesia. Therefore, it is essential to carefully assess the anatomy of the area planned for manipulation [10, 15]. The importance of this anatomical variation becomes evident when, during reinforcement of the anterior maxilla for implant placement, the canine pillar is used as a definitive landmark to support implants, where contact with the neurovascular bundles of the CS canal could jeopardize osseointegration and cause temporary or permanent paresthesia along with bleeding [10].
The CS canal can be identified through preoperative imaging examinations, particularly computed tomography, which allows visualization in thin slices without overlapping and, given its 3D nature, provides more reliable images of the maxillomandibular complex. CBCT imaging is the best examination for determining the location of the CS canal; thus, it is widely used for diagnosing and evaluating patients [26, 27]. CBCT imaging enables dentists to obtain the necessary details for diagnosis and treatment planning [10]. Since periapical and panoramic images usually cannot delineate this structure in detail, we decided to examine the CS canal using CBCT images. The use of CBCT images to identify the CS canal and determine its location, diameter, length, and variations is recommended to avoid potential iatrogenic complications at implant sites or other surgical procedures related to the anterior maxilla. Various clinical studies show that CBCT imaging is the best radiographic technique for observing the CS canal because it allows observation of the CS canal through its course in three planes: axial, coronal, and sagittal [2, 15].

Prevalence of the CS Canal

There are no previous reports in earlier studies determining the prevalence of these anatomical variations in a considerable number of CBCT images in Iran. Existing prospective studies in the database related to CS examined its presence using CBCT with sample sizes ranging from 100 to 1000 patients, in which the presence of the CS canal was highly variable, ranging from 8.17% [28] to 100% [24, 25]. In this study, 99 out of 311 women (31.8%) and 120 out of 269 men (44.6%) had a CS canal; the CS canal was significantly more prevalent in the male population. Similarly, in the study by Manhães et al., CS was more prevalent in males (37.97%) than females (34.86%)[10]. Tomrukçu et al. (2020), also reported a prevalence of 45.1% for males, compared to 27.5% for females [20]. In the study by Machado et al., 58% of males and 46.6% of females had a CS canal, and this difference was statistically significant [29]. In other studies by Warhekar et al. and Aoki et al., similar results were observed [15,23]. Von Arx et al. observed that CS in males had a prevalence of 33% compared to 22.7% in females, although the difference was not statistically significant [30].
However, these results are contrary to the study by Orhan et al., in which CS in females had a higher prevalence (72.2%) compared to males (69.7%) [6]. This contradiction could be due to several factors, such as:

- Only canals with a diameter of at least 1 mm were evaluated (excluding the Nasopalatine canal).
- The images were reviewed with a slice thickness of 1 mm.
- Possible racial differences (Turkish population).
- Some exclusion criteria considered in our study were not applied there (e.g., patients with implants, plates, cleft palate, edentulism, supernumerary/impacted teeth, or mixed dentition).

In the present study, a statistically significant relationship was observed between gender and the presence of this canal, but in the study by Wanzeler et al., no significant relationship was found [25]. This could be attributed to:

- Smaller sample size (only 100 patients studied).
- Racial differences (Brazilian population).
- Lack of exclusion criteria regarding patients with surgery, bone grafts, implants, trauma history, cleft palate, edentulism, supernumerary teeth, or low-quality CBCT images.

In general, scan resolution, slice thickness, and differences in sample size could cause some variations in different studies.
In the mixed group of 580 patients in the present study, the CS canal was observed in 219 CBCT images, equivalent to an overall prevalence of 37.8%. The reason for analyzing the mixed group is that some anatomical variations exhibit sexual dimorphism [10]. Similarly, the article by Manhães et al. (2016) reported a 36.2% overall prevalence [10]. The study by Shan et al. (2021) reported 36.9%, which is close to the present study's percentage, noting no statistically significant gender effect [3]. Also, Tomrukçu et al. (2020) found that 34.7% of their sample had a CS canal [20].
Meanwhile, in the study by de Oliveira-Santos et al. (2013), due to a smaller sample size (178 patients), only CS canals ≥1 mm were considered, racial differences (Belgian population) were noted, and the prevalence was 15.7% [1]. In the study by Yeap et al. (2022), due to a smaller sample size (201 patients),

racial differences (Australian population), slice thickness of 0.02 mm, evaluating only canine-to-canine regions, and not considering premolar and Incisive canal areas, a 98.5% prevalence was reported [24].

Both Yeap's and Aoki's studies (2020) have mentioned that studies reporting a prevalence of <50% for CS have only evaluated canals with ≥1 mm of diameter because it was assumed that only larger canals cause major clinical symptoms [15]. However, in our study, canals smaller than 1 mm were also evaluated because smaller vessels could also cause serious bleeding [1, 24].

In the study by Khojastepour and Akbarizadeh (2023), the CS canal prevalence was reported as 78.35% [31], which is higher than the present study.

The reasons could be:

- Smaller sample size (485 CBCTs),
- Lack of exclusion criteria (patients with pathological lesions, malformations, cleft palate, edentulism, supernumerary/impacted teeth, mixed dentition).

Conclusion

Considering the variations in the prevalence and location of the CS canal, in the examined Iranian population, 37.8% of individuals possessed this canal, indicating a relatively high prevalence in our country. Gender had a statistically significant effect on its prevalence, being more commonly observed in males than females. This study emphasized the use of CBCT before performing invasive procedures in anterior maxilla, as an area commonly used for implant placement, where the prevalence of the CS canal is very high. This could help diagnose and preserve anatomical structures such as CS, aiming to prevent complications during and after surgery, including neurovascular disorders, bleeding, and treatment failure. Furthermore, due to the possibility of nerve tissue damage during surgeries in the anterior maxilla, it is possible that at least part of undiagnosed facial pain in patients undergoing surgical interventions could be attributed to CS canal injury.

Therefore, the anterior maxilla, which was previously considered a relatively safe zone for implant placement, requires more careful attention during surgical procedures. Clinicians should be vigilant regarding the direction and depth of the implants placed in the alveolar bone to prevent neurovascular injuries. Clinicians must thoroughly assess the anterior maxilla for a complete differential diagnosis using CBCT images with small voxel size, and must be aware and trained for the correct identification of this structure; because neglecting the presence of this canal might result in irreversible damages and, in case of complications, delay the diagnosis of neurovascular injuries.

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