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Evaluation of the Frequency, Location, and Classification of Canalis Sinuosus in Cone-Beam Computed Tomography Images

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Objectives The canalis sinuosus (CS) is an auxiliary canal that encompasses the anterior superior alveolar nerve, artery, and vein. Understanding the location of this neurovascular structure during surgery can help prevent severe complications. This study aimed to assess the frequency, location, and classification of the CS using CBCT images.

Methods CBCT images of 200 patients were examined considering factors, such as age, sex, presence of impacted teeth, the diameter of the canal's orifice, and the location of the CS. In sagittal images, the distance from the CS to the buccal cortex, nasal floor, and alveolar crest was measured. Statistical analyses were conducted to compare variables between males and females, as well as between the right and left sides. The Chi-square, Fisher's exact test, Wilcoxon test, paired t-test, and Kruskal-Wallis tests were utilized for data analysis at a significance level of 5%.

Results The CS was detected in 135 cases (67.5%) on both sides, while it was not visible in 19 cases (9.5%). In 46 images (23%), the CS was observed only on one side. The canal was most commonly located in the lateral incisor region, followed by the canine area. The average distance from the canal's orifice to anatomical landmarks, such as the alveolar crest, buccal cortex, and nasal floor, was greater in males than in females. However, this difference was not significant between the right and left sides (P=0.56, P=0.31, P=0.98; respectively). When comparing males and females, no significant differences were observed in the occurrence of CS(P=0.728), the diameter of the canal(P=0.114), the buccopalatal position of the CS(P=0.800), or the canal location within the arch(P=0.132).

Conclusion It appears that CBCT and other 3D imaging techniques are essential for detecting the CS prior to performing surgery in the anterior maxillary region.

Keywords Cone beam computed tomography; Neurovascular, Diagnosis, Anatomy

Introduction

Lack of awareness about the neurovascular structures in the surgical field can result in serious complications. The nasopalatine canal is a well-known anatomical landmark in the premaxillary region that can be easily identified in conventional radiographs. Besides the nasopalatine canal, the premaxilla also contains accessory canals. [1] The canalis sinuosus (CS) is one of the accessory canals, which encompasses the anterior superior alveolar (ASA) nerve, artery, and vein. [2] This anatomical structure branches off from the infraorbital canal at its midpoint, which is located approximately 25 mm behind the infraorbital foramen. [3, 4] The branch of the CS moves laterally along the floor of the orbit before curving medially at the anterior wall of the maxillary sinus. It then passes beneath the infraorbital foramen and reaches the anterior margin of the nasal aperture, located in front of the anterior end of the inferior concha. Following the lower margin of the aperture, it continues towards the lingual aspect of canine and incisors and finally opens in front of the incisive canal. [5]

Certain authors have categorized the path of CS into three distinct sections: the orbital floor, the transverse facial, and the circumnarial. [2, 6, 7] Various surgical procedures in the premaxillary region, such as endodontic surgery, implant placement, bone grafting, surgical removal of canines and supernumerary teeth, cyst enucleation, or orthognathic surgery, have the potential to harm the neurovascular structure of CS. [8, 9] Various complications have been reported as a result of surgical damage to the CS, including extensive bleeding, temporary or permanent paresthesia, and failure of implant osteointegration. [10-13]

Contact between the neurovascular bundles and the implant can result in the formation of soft tissue at the implant interface. The CS is located close to the canine eminence, which is often used as a landmark for implant placement. This proximity increases the risk of complications during implant surgery. On conventional radiographs, the appearance of the CS may resemble a periapical lesion. Misdiagnosis could lead to unnecessary root canal therapy for anterior teeth. [10] In a case report by Shelly et al., CS was observed as a distinct radiolucency surrounding the apex of canine tooth. [3] Also, several studies have reported that the CS can appear as a periapical radiolucency in two-dimensional (2D) radiographs. This appearance can mimic a periapical inflammatory lesion of the maxillary anterior teeth. [12, 14, 15]

A small bony wall shields the anterior aspect of the CS, which can be easily fractured following maxillofacial trauma. The canal could be also disrupted during Le Fort I osteotomy or other oral surgeries. In such instances, the canal may become obliterated, or neuromas may form, potentially leading to neurosensory impairments. These impairments can include hypoesthesia, hyperesthesia, paresthesia, and neuropathic pain in canine and incisors, as well as post-traumatic mid-facial pain. [16] In 2D radiographs, such as periapical and panoramic images, the CS can be obscured by the superimposition of cortical or dense trabecular bone. This can lead to misdiagnosis of the CS as a periapical pathology. Therefore, when the presence of the CS is suspected in 2D radiographs, further evaluation using cone-beam computed tomography (CBCT) is recommended.

While numerous studies have reported the prevalence of the CS among different populations, there is limited data available about the variations in the canal position across these populations.[17, 18, 19] To the best of our knowledge, the present study is the first to report on the prevalence and anatomical features of the CS in Iranian population. The objective of this study was to assess the prevalence and anatomical position of CS using CBCT imaging.

Methods and Materials

According to a study by Manhaes[20], the prevalence of the CS was reported to be 36%. Using a formula to estimate a ratio with an error level of 5% and an accuracy of 7%, the sample size was calculated to be 181 individuals. However, to account for a potential sample drop-out of 10%, the final sample size was adjusted to 200 individuals. In this retrospective study, 200 CBCT scans from patients referred to the radiology department, Mashhad Dental School, Mashhad University of Medical Science, were selected. No interventions were performed on the patients for this study; only CBCT scans that were already available in the archive were used. All patient information was kept confidential in accordance with ethical guidelines (Ethical Number: IR.mums.sd.REC 1394.293).

The patients were categorized into three age groups: <26 years, 26-45 years, and >46 years. Any patients with a history of surgery, trauma, or pathological lesions in the anterior region of the maxilla were excluded from the study. The 3D images were all obtained using the same device (Planmeca ProMax 3D Classic, Helsinki, Finland) under identical exposure settings (54-84 kVp, 10 mA, 12 seconds). These images were evaluated using Romexis software (version 3.8.0) in various slices, each with a thickness and interval of 1 mm. Demographic data, including age, sex, and the presence of impacted, missing, and supernumerary teeth, were recorded for each patient. If the position of a tooth hindered the diagnosis, that particular sample was excluded from the study. After identifying landmarks on cross-sectional slices, the presence of the canal was confirmed by examining coronal images. The distances from the canal to three reference points, namely the nasal floor, the buccal cortex, and the alveolar crest, were measured using these cross-sectional slices (Figure 1).[20]

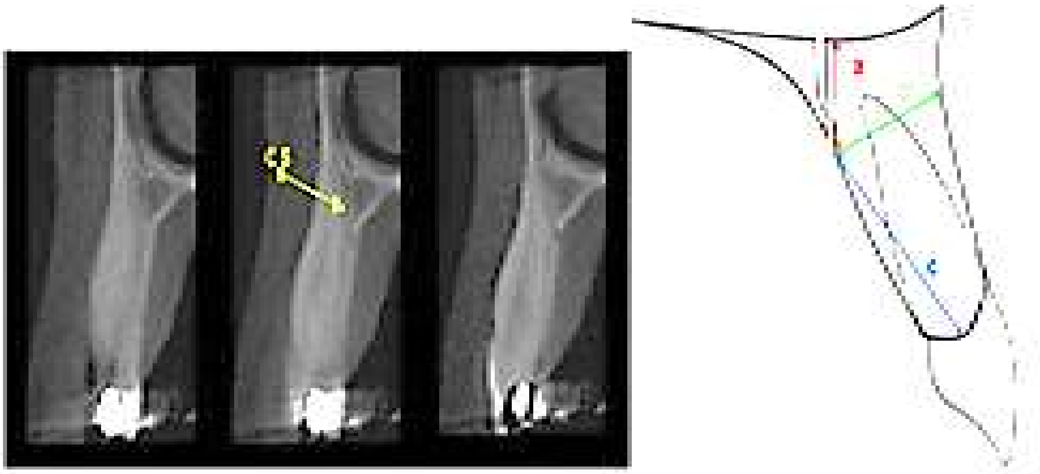

Figure 1:a. NC (nasal cavity) – distance between the CS and the nasal cavity floor (red arrow); b. BC (buccal cortical) – distance from the emergence of the CS to the buccal cortical bone edge, straight line (green arrow); and c. RC (ridge crest) – distance from the emergence of the CS to the most prominent point of the crest of the alveolar ridge (blue arrow).[20]

According to the classification by Oliveira et al., eight distinct areas were defined. These included the areas between the central incisors, between the lateral and central incisors, adjacent to the lateral incisor, between the lateral incisor and canine, adjacent to the canine, adjacent to the first premolar, lateral to the incisive foramen, and posterior to the incisive foramen.[3] The presence of the CS, its position in the buccopalatal axis (buccally, in the middle, and palatally), its position in the dental arch, and the diameter of the canal were all recorded. Additionally, the distance of the CS from the buccal cortex, nasal floor, and alveolar crest was documented across different age groups. The existence of the CS was evaluated in various planes (Figure 2).

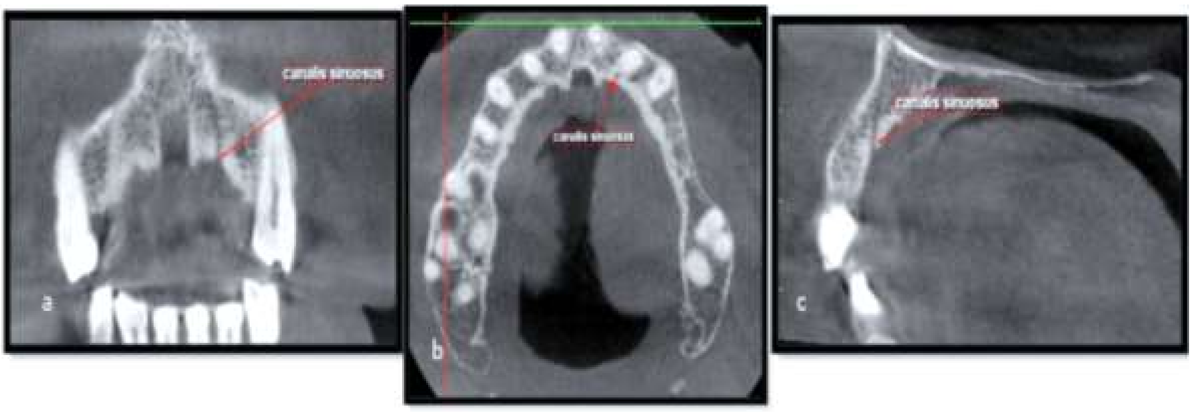

Figure 2: Canalis Sinuosus in different sections (a:coronal ,b:axial,c: sagittal)

Statistical analysis was performed using SPSS Version 16.0. The Shapiro-Wilk test was used to assess the normality of the data. The Chi-square test, Fisher's exact test, independent t-test, and Wilcoxon test were used to compare different variables between males and females, as well as between the left and right sides.

Results

In the present study, a total of 200 radiographs were evaluated. Among these, 111 belonged to women (55.5%) and 89 to men (44.5%). The average age of the participants was 42.7±13.2 years. The CS was observed bilaterally in 135 images (67.5%) and unilaterally in 46 images (23%). In 19 images (9.5%), the CS was not detectable. The CS was observed in 196 women (54.7%) and 162 men (45.2%). The most common position of the CS was palatally, seen in 346 sites (96.6%). The CS was located at the site of the lateral incisor in 96 cases (36.8%) and in the canine region in 85 cases (23.74%).
The results of various variables, including the presence of the CS, the diameter of the CS, and the position of the CS in the buccopalatal axis, are reported in Table 1.

Table 1- The summary of data. The results were reported separately in males and females

Variables		Genders		Total
		Female	Male	
Number of evaluated CBCT images		111(55.5%)	89 (44.5%)	200(100%)
The presence of canal in both sides		58(42.9%)	77(57 %)	135(67.5%)
No presence of CS		12(63.15%)	7(36.8%)	19(9.5%)
The presence of CS just in one side	Right	5(33.3%)	10(66.6%)	15(32.6%)
	Left	17(54.8%)	14(45.1%)	31(67.3%)
	Total	22(47.8%)	24(52.1%)	46(23%)
The presence of accessory canal		15(46.8%)	17(53.1%)	32(16%)
The diameter of the orifice of CS	1mm>	125(58.1%)	90(47.8%)	215(60%)
	1mm≤	71(49.6%)	72(50.3%)	143(39.9%)
The position of CS in buccopalatal axis	Buccal	0	0	0
	Palatal	189(54.6%)	157(45.3%)	346(96.6%)
	Middle	7(58.3%)	5(41.6%)	12(3.3%)
The position of CS in dental arch	Central	19(73%)	7(26.9%)	26(7.2%)
	Between central and lateral	28(68.2%)	13(31.7%)	41(11.4%)
	Lateral	48(50%)	48(50%)	96(36.8%)
	Between canine and lateral	21(58.3%)	15(41.6%)	36(10%)
	Canine	42(49.4%)	43(50.5%)	85(23.7%)
	Premolar	35(53.8%)	30(46.1%)	65(18.1%)
	Adjacent to incisive foramen	3(37.5%)	5(62.5%)	8(2.2%)
	Posterior to incisive foramen	0(0%)	1(100%)	1(0.2%)

No significant differences were found between males and females in terms of the following variables: the presence of the CS, the diameter of the canal, the buccopalatal position of the canal, the position of the canal in the arch, and the presence of accessory canals. Additionally, these variables did not show significant differences across different age groups.

The Wilcoxon test indicated that the average distances from the CS to the buccal cortex, nasal floor and alveolar crest in men were significantly greater than those in women. However, there was no significant difference between the right and left sides in either gender. The distances from the canal to the buccal cortex, nasal floor, and alveolar crest are reported in Table 2.

Gender	Distance (mm)	Side	mean±SD	p-value
Female	BC	Right	8.7±2.3	0.91
		Left	8.7±2.0	
	NC	Right	10.6±4.0	0.96
		Left	10.6±4.3	
	RC	Right	12.0±4.8	0.25
		Left	12.3±50	
male	BC	Right	9.8±2.1	0.157
		Left	9.2±2.4	
	NC	Right	12.3±4.4	0.97
		Left	12.1±4.4	
	RC	Right	13.2±5.3	0.85
		Left	13.3±5.6	
Total	BC	Right	9.1±2.3	0.31
		Left	9.0±2.2	
	NC	Right	11.3±4.3	0.98
		Left	11.3±4.4	
	RC	Right	12.5±5.11	0.56
		Left	12.8±5.3	

In our study of 18 patients with 23 impacted teeth, the CS was observed in 15 impaction sites, accounting for 65.2% of the impacted teeth. The canal diameter was greater than 1 mm in only three of the impacted teeth (20%). The canal position was palatal in 14 of the impacted sites (93.3%), and the middle position was only observed in one impacted canine. The most common position of the CS among patients with impacted teeth was the canine region. In four impaction sites (26.6%), the CS position was close to the canine. The average distances from the CS to the buccal cortex and from the CS to the nasal floor at the impaction sites were 9.5 mm and 11.84 mm, respectively.

Discussion

Prior to surgical procedures, it is crucial to identify high-risk anatomical structures. The CS is one such important anatomical variation. If an implant invades the CS, it could lead to implant failure. This can occur because the proximity of the implant to the CS stimulates fibrointegration instead of osseointegration, compromising the success and stability of the implant. In some instances, the CS is entirely adjacent to the alveolar ridge, which could inevitably harm the neurovascular structure during the implant procedure. CBCT is the most precise imaging technique in dentistry. It provides multiple slices and enhanced visualization of bony structures. [17]

Violation of the CS during surgical procedures can result in severe complications, such as bleeding, sensory abnormalities, and integration failure. It is crucial to acquire 3D images to ascertain the canal's position and its proximity to other anatomical structures, as surgical interference with the CS can lead to serious issues. Gurler et al. demonstrated that the distance between the CS and impacted teeth was less than 1 mm in some instances of horizontally impacted canines. Therefore, a cautious surgical approach is advised in these situations to avoid damaging the CS during intervention. [5]

Machado et al. reported two cases of postoperative pain after implant placement near the accessory canals of CS. In one of these cases, immediate pain relief was seen after implant removal. [18] De-Oliveria-Santos et al. suggested seven potential positions for the CS in the hard palate. These included the area between the central incisors, the space between the central and lateral incisors, next to the lateral incisor, canine and first premolar, to the side of the incisive foramen, and behind the incisive foramen. [3]

In the present research, the most common location for the CS was near the lateral incisor (36.81%). Other common sites included the canine region (23.74%), the premolar region (18.15%), between the central incisors (11.45%), and between the lateral incisor and canine (10.05%). The study by Olivera et al. found the CS position to be most frequently between the incisor and canine. Orhan et al. detected 44.72% of accessory canals in the inter-central maxillary distance.

In the present research, the occurrence of CS in patients with impacted canines was similar to that in other patients, at a rate of 65.2%. The canal was situated palatally in 93.3% of these patients, and in 26.6% of cases, the canal was next to the impacted canine. In all cases of impacted maxillary canines, Gruler et al. noted the presence of the CS.[5] The distance between the horizontally impacted canine was found to be less than that of vertically and obliquely impacted canines. The authors suggested that utilizing 3D imaging prior to surgery for maxillary impacted canines is beneficial for identifying the CS.

In the present research, the CS was located palatally in 96.6% of cases, and in 3.4% of cases, the canal was in a central position. We did not observe any canals positioned buccally.

According to the results of a study by Machado et al.[8], the path of accessory canals concluded at the palatal side of the maxillary anterior teeth. In the present research, the majority of cases (60.05%) had a canal diameter of less than 1 mm. A larger proportion of cases (84.61%) with a canal diameter of less than 1 mm were observed in patients with impacted maxillary canines. The diameter of accessory canals was less than 1 mm in 52.5% of patients. The study by De Olivera et al. reported a mean canal diameter of 1.4 mm[3]. The findings from various studies on the prevalence and characteristics of CS are summarized in Table 3.

One of the limitations of this study was the limited number of CBCTs available for individuals under 26 years of age. The archives of the Radiology Department at Mashhad Dental School, where the CBCT images were sourced, had a higher number of patients seeking implants, resulting in a smaller collection of images from the age group of <26 years. Another limitation was the absence of comparable studies within the Iranian population for analysis. To enhance the understanding of this anatomical structure, we recommend conducting similar studies across different demographics in Iran, particularly among younger age groups, such as adolescents and children.

Conclusion

While the CS has been characterized as an infrequent anatomical variation; various studies, including the present research, demonstrated that this variation is common in certain populations. In this research, the CS was observed in 90.5% of cases. Given that this anatomical structure houses the alveolar nerve and vessels, identifying this variation is crucial to avoid potential complications, such as bleeding and sensory disturbances. This structure is often not visible in conventional radiographs; therefore, 3D imaging, such as CBCT, appears to be necessary before surgery in suspected areas.

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Conflict of Interest

No Conflict of Interest Declared ■

Table 3- The data and results of different studies about the prevalence and characteristics of CS.

Authors	Country	Sample size	Frequency	Diameter of canal and distances to anatomic landmarks	Findings
Oliveira et al. (2013) [3]	Belgium	178	7.8%	The average diameter of additional foramina found in the anterior region of maxilla was 1.4 mm (1–1.9 mm).	15 % of population studied had additional foramina in the anterior palate that were at least 1 mm in diameter. In 18 cases, AFP was associated with bony canals with upward or oblique direction toward which may represent additional branches of the nasopalatine. In 14 cases, the canal presented as a direct extension of the canalis sinuosus, in an upward direction laterally to the nasal cavity aperture. In two cases, the canal was observed adjacent to the incisive and joined the nasopalatine canal superiorly
Von Arx et al. (2013) [14]	Switzerland	176	27.8%	The mean diameter of accessory canals other than nasopalatine canals was 1.31 ± 0.26 mm.	The prevalence of accessory canals was not different between males and females. Diameter of accessory canals was not affected by age and gender. The most prevalent position of accessory canal was posterior to the central incisors. More than half of these canals communicated with the canalis sinuosus on the same side probably representing a direct extension of the neurovascular content of the canalis sinuosus into the anterior maxilla.
Wanzeler et al. (2015) [19]	Brazil	100	88%	The distance between the end of CS and the alveolar bone crest was 24.83 mm in men and 12.98 mm in women. This distance was significantly higher in males. The initial diameter of canal was 0.79 mm in right side and 0.74 mm in left side. The terminal diameter of canal was 0.81 mm in both left and right side.	Only in one case the CS was seen unilaterally. The prevalence of CS was not significantly different between males and females. Regarding CS's diameter, there was no significant change related to gender and neither between the left and right sides, but there was a difference between the initial and terminal portions.
Manhaes et al. (2016) [20]	Brazil	500	36.2 %	The mean distance of CS from anatomic landmarks Crest ridge : right (7.71 mm) and left (9.28mm) Buccal cortical : right (6.83mm) and left (7.94mm) Nasal cavity: right (11.05 mm) and left (10.44mm)	There was no significant difference between right and left sides according to the classification of CS location. The most common location for both sides was beside the incisive foramen. The mean distance Therefore, there was a difference in the distances from the CS to the alveolar ridge crest and to the buccal cortical bone in this group.
Machado et al. (2016) [18]	Brazil	1000	100%	The mean diameter of accessory canals (only for canals with diameter greater than 1mm) was 1.19 mm.	The frequency of accessory canals of CS was significantly higher in males than females. In more than 90% of patients the end of ACs were located palatally to anterior maxillary teeth but buccal position and transverse positions were seen. The distribuation of accessory canals between age groups and both sexes was not statistically different. There was not statistically significant relationship between age and number and diameter of accessory canals
Ghandourah et al (2017) [21]	Germany	219 (201 adults and 18 adolescents)	100%	In adults 82.1% of CSs was ≥1mm. 77.8% of adolescents the CS was measured to be ≥1mm.	CS was seen bilaterally in all samples. But the frequency of accessory canals of CS was 67.6 % in adult group and 44% in adolescent group. The frequency of accessory canals was not different between males and females.
Gurler et al. (2017) [5]	Turkey	111 patients with impacted canines	100%	The mean diameter of canal was 1.37 mm. The mean diameter was significantly higher in males than females. The diameter of canal was not statistically different between sides with impacted canine and the side without impacted teeth. Also the mean diameter of accessory canals was 1.06 mm. The mean distance between CS and impacted canine was about 5.75 mm. This distance was significantly shorter in horizontally impacted canines than vertically or oblique impacted.	The CS detected bilaterally in all tomographic images. Accessory canals were seen in 6 patients. The mean diameter of canal was significantly larger in males than females. In all samples the terminal end of CS was near the incisive canal on the nasal floor. Only in 1 case the terminal portion of CS located superiorly to the nasopalatine canal.
Orhan et al. (2018) [4]	Turkey	1460	70.8%		A total of 6668 accessory canals were found in 1460 CBCT images. 1034 (70.8%) of 1460 images had at least one accessory canal of CS. Maxillary intercentral region is the area where accessory canals were seen most frequently (n = 653, 44.72%).

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