Evaluation of Extension Type of Canalis Sinuosus in the Maxillary Anterior Region: a CBCT Study

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Objective: *To evaluate the extension of canalis sinuosus (CS) into the alveolar crest for surgical reference in the anterior maxilla.*
Methods: *In this cross-sectional study, 485 CBCT images were evaluated in three orthogonal planes (axial, coronal and sagittal). The type of extension of CS into the alveolar ridge in the anterior maxilla was evaluated. The alveolar ridge was divided into four equal parts in a vertical and horizontal direction. In a vertical direction from apical to incisal and in a horizontal direction from labial to palatal, the four parts were designated as types 0, I, II and III, respectively. The extension of CS into the alveolar ridge was then traced.*
Results: *CS was present in 380 subjects (78.35%), and the extension type was unilateral in 217 of them (57.11%) and bilateral in 163 of them (42.89%). There was no significant relationship between incidence of CS and sex. Regarding the distribution of vertical and horizontal types, type II (the third quadrant of the ridge from apical to incisal and from labial to palatal, respectively) was significantly more prevalent than other types.*
Conclusion: *The most common location of CS into the alveolar ridge in both horizontal and vertical directions was type II (which is not close to the cortex). Awareness about the presence and possible locations of CS helps to reduce the risk of unjustifiable postoperative complications.*

Key words: *alveolar process, CBCT, incidence, maxilla*
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The canalis sinuosus (CS) is a neurovascular structure which was first introduced by Jones[1] in 1939. It is a branch of the anterior superior alveolar nerve and vessels, and originates from the infraorbital foramen, extending laterally towards the nasal cavity, ending in the anterior alveolar maxillary region[2]. This region has thin cortical bone, which makes it susceptible to invasion during surgical procedures[3]. The increasing amount of surgical manipulation that takes place in this region requires surgeons to have thorough knowledge about the anatomical structures prior to surgery[4-7].

Several studies have evaluated the presence and frequency of CS in the last decade. In 2012, Neves et al[6] described CS a rare anatomical structure, but in further articles it was reported as being common[8-10]. Recently, Brücker et al[4] and Lello et al[11] reported CS to be present in 97% and 100% of subjects, respectively. In fact, CS is now considered to be a normal variation rather than a rare anatomical landmark.

The main aspects of this topic that have been evaluated to date include the distance between CS and the surrounding structures, and the mesiodistal location of CS regarding the teeth in that area. Manhães Júnior et al[12] and Tomrukçu et al[13] measured the distance between CS and three surrounding structures (nasal cavity floor, buccal cortical edge and alveolar ridge crest). They reported these distances numerically, and both assumed that CS shows significant variation in its location relative to these structures. The horizontal and vertical distance of CS from the orbit and nasal cavity was measured by Lello et al[11], and they detected minor

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variations in the distance of CS from surrounding structures between various individuals.

The mesiodistal location of CS was classified first by de Oliveira-Santos et al[5]. They represented the distribution of CS relative to the teeth/incisive foramen, and found the canine region to be the predominant location. Shan et al[14] classified the location and opening of CS regarding the teeth and reported that the predominant location was between the central and lateral incisors.

In all the studies that have been published thus far, there has been profound variation in alveolar ridge dimensions in different people. Accordingly, most accurate knowledge regarding the extension of CS into the alveolar ridge can be acquired by evaluating the ratio of extension of CS into the ridge proportionally, instead of addressing the extension using numbers. There has not been any such assessment regarding CS up to now.

The use of CBCT enables a low dose of radiation exposure but detailed bone evaluation for diagnostic aims such as assessment of neurovascular structures, as it has the highest spatial resolution for bone evaluation[15,16].

The aim of this study is to assess the course of extension of CS into the alveolar ridge proportionally. Obtaining this information by means of CBCT would be beneficial in minimising the risk of injury to CS during surgical procedures in the anterior maxilla.

Materials and methods

The protocol of current study was approved by the Ethical committee of Shiraz University of Medical Sciences (protocol no. IR.SUMS.DENTAL.REC.1398.124).

Study design

CBCT images captured from June 2016 to June 2020 from the Oral & Maxillofacial Radiology Department were evaluated. The inclusion criterion was images with the field of view including the whole maxilla. The exclusion criteria were poor-quality radiographs, artefacts due to metallic restorations which led to false interpretation of the image, and subjects with a history of trauma/manipulation in the anterior maxilla. Systematic random sampling was employed. Finally, we selected 485 high-quality CBCT scans with a desirable field of exposure from the archive for further assessment. Informed consent was provided by the subjects when the images were captured, giving permission for their radiographs to be used without their names for further research.

CBCT imaging

The whole radiographs were captured under standard conditions using one device (NewTom VGI EVO CBCT unit; Bologna, Italy) with 75-110 Kvp tube voltage and 1-32 mA tube current, and the field of view size for all scans was the whole maxilla. The most recent CBCT innovation, the automatic exposure control mechanism, was used. As a result, the exposure parameters differed from patient to patient, based on their anatomy and size. The mean voxel size was 0.3 mm.

All radiographs were evaluated simultaneously by two oral and maxillofacial radiologists. The evaluation was done in three orthogonal planes (axial, coronal and sagittal) using NNT Viewer Software (NNT 9.21, NewTom).

Imaging analysis

In the first step, to detect the presence of CS, we evaluated continuous coronal cross-sectional cuts. The slice thickness and distance between the slices were both selected as 0.5 mm for more detailed examination of the area (Fig 1).

After that, in all subjects in whom CS was found to be present in coronal sections, we explored the maxilla by scrolling the axial view to confirm this finding (Fig 2).

In subjects in whom CS was confirmed to be present in both the coronal and axial views, we evaluated its extension into the alveolar ridge in sagittal view (Fig 3). We divided the alveolar ridge into four equal parts (0, I, II and III), in both an apico-incisal (vertical) and labio-palatal (horizontal) direction.

In the vertical aspect, we divided the ridge from the nasal floor to the alveolar ridge crest into four equal parts. The most apical compartment of the ridge (which was nearest to the nasal floor) to the most incisal part (which was nearest to the alveolar ridge crest) were designated as type 0 to III, respectively (from an apical to an incisal direction) (Fig 4).

In the horizontal aspect, the ridge was divided into four equal parts too. The most labial part to the most palatal part were labelled as type 0 to III, respectively (from a labial to a palatal direction) (Fig 5).

We traced the extension of CS and its terminal portion into the alveolar ridge in sagittal view. Based on the termination of CS in one of the mentioned vertical and horizontal quadrants, the subjects were categorised into four vertical and four horizontal types individually.

Additionally, the most anterior extension of CS regarding the teeth was specified. To this end, the extensions to the central incisor, lateral incisor, canine

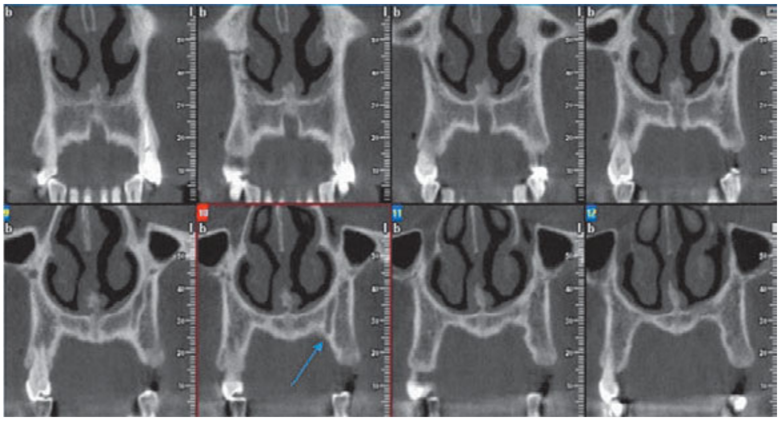

Fig 1 Detection of CS in coronal view of CBCT.

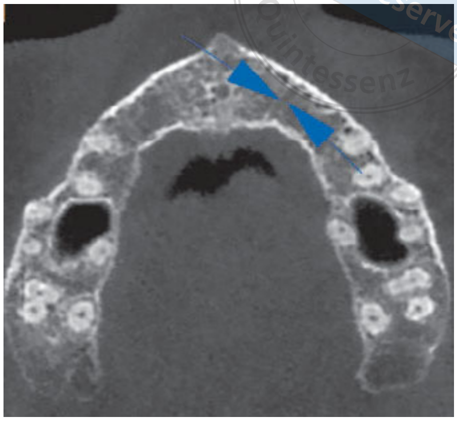

Fig 2 Confirmation of CS in axial view of CBCT.

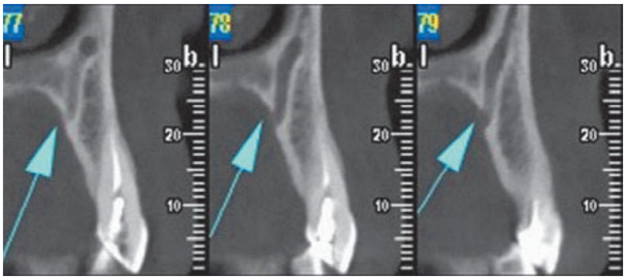

Fig 3 Evaluation of extension of CS in sagittal view of CBCT.

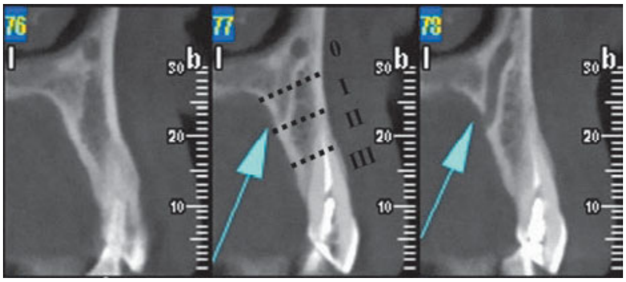

Fig 4 Division of the alveolar ridge into four equal parts (0, I, II and III) in an apicoincisal (vertical) direction. The most apical compartment of the ridge to the most incisal part was designated as type 0 to III, respectively (from an apical to an incisal direction).

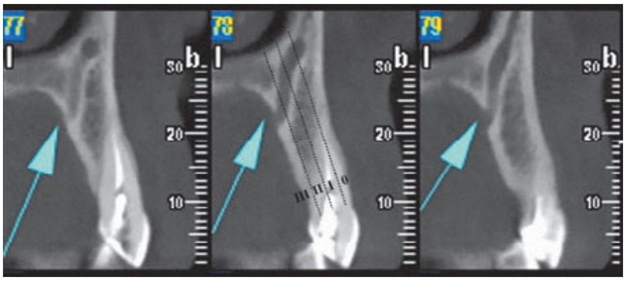

Fig 5 Division of the alveolar ridge into four equal parts (0, I, II and III) in a labiopalatal (horizontal) direction. The most labial compartment of the ridge to the most palatal part was designated as type 0 to III, respectively (from a labial to a palatal direction).

and first premolar were categorised as type 0, I, II and III, respectively.

We also evaluated the mean diameter of CS in the middle part of this structure in all subjects, and the participants were classified into two groups based on this diameter: larger than 1 mm or smaller than 1 mm.

Statistical analysis

SPSS software version 18.0 (SPSS, Chicago, IL, USA) was used for statistical analysis. A chi-square test was used to assess the correlation between sex and frequency of CS, between sex and unilateral/bilaterality of CS, and also between sex and diameter type of CS. A Fisher exact test was applied to evaluate the frequency of horizontal and vertical extension types of CS into the alveolar ridge. *P* values < 0.05 were considered statistically significant.

Results

Among the 485 participants in the present study, 228 (47.01%) were male and 257 (52.99%) were female. The mean age of the subjects was 38.50 years. CS was present in 380 subjects (78.35%). Of these, it was unilateral in

Table 1 Frequency, unilaterality/bilaterality and diameter of CS and their relation with sex.

Variable		Sex		OR	95% CI	*P* value*
		Female	Male			
CS	Present	201 (78.21%)	179 (78.50%)	0.969	0.62–1.49	0.888
	Not present	56 (21.78%)	49 (21.49%)			
	Unilateral	113 (56.21%)	104 (58.10%)	1.07	0.49–2.32	0.866
	Bilateral	88 (43.78%)	75 (41.89%)			
	Diameter ≥ 1 mm	23 (11.44%)	35 (19.55%)	0.523	0.21–1.30	0.158
	Diameter < 1 mm	178 (88.55%)	144 (80.44%)			

*$P < 0.05$. CI, confidence interval; OR, odds ratio.

Table 2 Comparison of extension of CS in different planes (vertical, horizontal and most anterior extension).

Plane	Type				
	0	I	II	III	*P* value
Vertical	15 (3.94%)	145 (38.15%)	200 (52.63%)	20 (5.26%)	0.040
Horizontal	11 (2.89%)	33 (8.68%)	206 (54.21%)	130 (34.21%)	0.000
Most anterior extension	22 (5.78%)	246 (64.73%)	83 (21.84%)	29 (7.63%)	0.078

217 individuals (57.11%, 113 women and 104 men), and bilateral in 163 cases (42.89%, 88 women and 75 men). There was no significant relationship between sex and unilaterality/bilaterality of this structure (Table 1).

The prevalence of CS among men and women was 179 (78.50%) and 201 (78.21%), respectively. There was no significant relationship between the incidence of CS and sex ($P = 0.888$, CI 0.63–1.49 odds ratio [OR] 0.97) (Table 1).

Among the subjects in whom CS was present, 80.44% and 88.55% of men and women, respectively, had a diameter smaller than 1 mm. There was no association between the diameter of CS and sex ($P = 0.158$, CI 0.21–1.30, OR 0.523) (Table 1).

Table 2 presents the vertical and horizontal distribution and most anterior extension of all 380 subjects with CS in both sexes. There was no significant difference regarding the most anterior extension of CS among subjects, although type II (lateral incisor tooth) was the most prevalent type ($P = 0.078$).

There was a significant difference between the frequencies of different vertical types. Type II was significantly more prevalent than other types, followed by types I, III and 0 ($P = 0.040$) (Table 2).

Regarding the horizontal direction, the prevalence of the four types differed significantly. The most common type was again type II, followed by types III, I and 0 (Table 2).

Discussion

CS is a common but often overlooked anatomical landmark extending from the infraorbital foramen to the anterior maxilla[2]. Precise evaluation of CS and its extension into the alveolar ridge is essential for avoiding encroachment to this neurovascular structure.

We found the frequency of CS to be 78.6%. The prevalence of CS was found to vary in previous articles due to a combination of factors. As there is no consensus about the diameter for detection of CS, Oliveira-Santos et al[5], Shan et al[14] and von Arx et al[17] determined that the diameter was just over 1 mm and reported a frequency of 15.7%, 36.9% and 27.8%, respectively; however, in other studies by Orhan et al[10], Brücker et al[4], Wanzeler et al[18] and Gurler et al[19], like as in this study, structures with a diameter lower than 1 mm were also included and higher frequencies were reported, namely 70.8% ,97.4%, 88.0% and 100.0%, respectively. The frequency of CS with a diameter smaller than 1 mm was found to be 84.73% in the present study, and there is an accepted notion that encroachment into even minute canals under 1 mm may lead to neurovascular symptoms[5]. Based on this view, evaluation of canals < 1 mm also seems essential. Ethnic discrepancies also cause differences in the frequency of anatomical variations[4,5,14,20]. The other plausible justification would be due to differences in the quality of CBCT devices and the selected pixel size for images, which differs in each article.

In the present study, the diameter of CS was smaller than 1 mm in most cases. There was an insignificant difference between diameters in both sexes. This was in accordance with the findings of Khabadze et al[8]. In contrast, Shan et al[14] reported the diameter of CS to be larger in men. We also found no significant difference in the prevalence of CS between the sexes; this was in line with the findings of Shan et al[14], Orhan et al[10] and de Oliveira-Santos et al[5]. Conversely, Khabadze et al[8], Machado et al[21], Tomrukçu et al[13] and Aoki et al[22] reported a higher frequency of CS in men. Although this research suggests that CS is mostly unilateral, Aoki et al[22] found a significantly higher percentage of bilateral cases. The reason for all these differences could be ethnic diversity.

The notion of evaluating the extension of CS into the maxillary alveolar process was proposed by de Oliveira-Santos et al[5], who classified the mesiodistal location of CS. According to their classification, there are seven regions for extension of CS: the central incisor region, between the central and lateral incisors, the lateral incisor region, canine region, first premolar region, lateral to the incisive foramen and posterior to the incisive foramen. They determined that the most common location was near the incisors or canines[5]. We found the lateral incisor to be the most common location for extension of CS, which is consistent with the findings of some other studies[8,9,12]. This result aligns with those of Aoki et al[22], Shan et al[14] and von Arx et al[17], who established the incisors as the most common location.

We evaluated the ratio of extension of CS into the alveolar ridge by dividing the ridge into four parts both horizontally and vertically. In the vertical aspect, we designated the four parts of the ridge from coronal to apical as 0, I, II and III, respectively. In the horizontal aspect, we named the four parts of the ridge from labial to palatal 0, I, II and III, respectively.

The prevalence of extension of CS into the alveolar ridge in a labiopalatal direction for the mentioned types was II > III > I > 0. This result approximately agrees with the findings obtained in previous studies. Several studies reported the location of CS opening in the palatal aspect of the alveolar ridge[8,13,17,21].

The present results illustrate that although CS is most commonly extended in the third quadrant of the ridge (from labial to palatal), other parts, even the most labial quadrant, are possible regions for CS expansion. This highlights the importance of thorough examination of the alveolar ridge before any surgical manipulation that cannot be achieved other than through CBCT examination. Intraoral and panoramic views are insufficient for presurgical assessment of the anterior maxilla, which was previously considered a safe region, because the field of view is so limited in them and there are superimpositions.

The present evaluation of CS into the alveolar ridge in a vertical direction revealed that the spread order of CS extension for the mentioned types was II > I > III > 0. The apico-incisal location of CS has only been evaluated previously in two studies, to the best of the present authors' knowledge[12,13]. Júnior et al[12] and Tomrukçu et al[13] assessed the distance between CS and the alveolar crest and reported a statistically significant difference between subjects. As for the horizontal direction, the most common location for CS in a vertical direction was type II (the third quadrant of the ridge that is not closest to the alveolar ridge). As mentioned previously, detailed examination of the entire alveolar ridge in both horizontal and vertical directions for detection of CS is essential.

Clinical knowledge about the frequency and possible locations of CS would be beneficial in different fields and may be especially helpful for surgeons. Even subtle manipulation in the anterior maxilla require detailed evaluation of the entire ridge to prevent encroachment onto the neurovascular structures, and this needs to be done using advanced modalities as it may be overlooked in conventional imaging. This reduces the risk of unjustifiable postoperative complications.

In the present study, we evaluated CS exclusively in dentate subjects. A potential limitation of the study is its lack of evaluation of CS extension type in edentulous subjects compared to dentate patients. Also, considering the diverse reports about the frequency of CS among populations, extension type of CS may vary in different ethnic groups; thus, evaluation of extension type of CS in other populations is recommended.

Conclusion

There is diversity in the frequency of CS among different populations. In present study, the frequency was reported to be 78% and there was no significant difference between the sexes. In most cases, CS was unilateral and the diameter was smaller than 1 mm, with no significant difference between the sexes. The most common mesiodistal location of CS was the lateral teeth. The most common opening location of CS into the alveolar ridge in both horizontal and vertical directions was type II, which is not closest to the alveolar ridge, the third quadrant of the ridge from labial to palatal and from apical to incisal, respectively.

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Conflicts of interest

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

Author contribution

Both authors participated in the data collection process, statistical analysis and writing of this article.

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References

1. Jones FW. The anterior superior alveolar nerve and vessels. J Anat 1939;73:583–591.
2. Shintaku WH, Ferreira CF, Venturin JS. Invasion of the canalis sinuosus by dental implants: A report of 3 cases. Imaging Sci Dent 2020;50:353–357.
3. Ferlin R, Pagin BSC, Yaedú RYF. Evaluation of canalis sinuosus in individuals with cleft lip and palate: A cross-sectional study using cone beam computed tomography. Oral Maxillofac Surg 2021;25:337–343.
4. Brücker MR, Pohren D, Morosolli ARC. Analysis of Canalis sinuosus prevalence by cone beam computed tomographs (CBCT). Int J Appl Dent Sci 2021;7:425–428.
5. de Oliveira-Santos C, Rubira-Bullen IR, Monteiro SA, León JE, Jacobs R. Neurovascular anatomical variations in the anterior palate observed on CBCT images. Clin Oral Implants Res 2013;24:1044–1048.
6. Neves FS, Crusoé-Souza M, Franco LC, Caria PH, Bonfim-Almeida P, Crusoé-Rebello I. Canalis sinuosus: A rare anatomical variation. Surg Radiol Anat 2012;34:563–566.
7. Arruda JA, Silva P, Silva L, et al. Dental implant in the canalis sinuosus: A case report and review of the literature. Case Rep Dent 2017;2017:4810123.
8. Khabadze Z, Taraki F, Mordanov O, et al. Analysis of accessory canals as important anatomical structures in the anterior maxilla with cone beam computed tomography. J Int Dent Medical Res 2020;13:162–165.
9. Anatoly A, Sedov Y, Gvozdikova E, et al. Radiological and morphometric features of canalis sinuosus in Russian population: Cone-beam computed tomography study. Int J Dent 2019;2019:2453469.
10. Orhan K, Gorurgoz C, Akyol M, Ozarslanturk S, Avsever H. An anatomical variant: Evaluation of accessory canals of the canalis sinuosus using cone beam computed tomography. Folia Morphol (Warsz) 2018;77:551–557.
11. Lello RIE, Bornstein MM, Suter VGA, Bischof FM, von Arx T. Assessment of the anatomical course of the canalis sinuosus using cone beam computed tomography. Oral Surg 2020;13:221–229.
12. Manhães Júnior LR, Villaça-Carvalho MF, Moraes ME, Lopes SL, Silva MB, Junqueira JL. Location and classification of Canalis sinuosus for cone beam computed tomography: Avoiding misdiagnosis. Braz Oral Res 2016;30:e49.
13. Tomrukçu DN, Köse TE. Assesment of accessory branches of canalis sinuosus on CBCT images. Med Oral Patol Oral Cir Bucal 2020;25:e124–e130.
14. Shan T, Qu Y, Huang X, Gu L. Cone beam computed tomography analysis of accessory canals of the canalis sinuosus: A prevalent but often overlooked anatomical variation in the anterior maxilla. J Prosthet Dent 2021;126:560–568.
15. Van Dessel J, Nicolielo LF, Huang Y, et al. Accuracy and reliability of different cone beam computed tomography (CBCT) devices for structural analysis of alveolar bone in comparison with multislice CT and micro-CT. Eur J Oral Implantol 2017;10:95–105.
16. Khojastepour L, Movahhedian N, Zolghadrpour M, Mahjoori-Ghasrodashti M. Assessment of the relationship between the maxillary sinus and the canine root tip using cone beam computed tomography. BMC Oral Health 2021;21:338.
17. von Arx T, Lozanoff S, Sendi P, Bornstein MM. Assessment of bone channels other than the nasopalatine canal in the anterior maxilla using limited cone beam computed tomography. Surg Radiol Anat 2013;35:783–790.
18. Wanzeler AM, Marinho CG, Alves Junior SM, Manzi FR, Tuji FM. Anatomical study of the canalis sinuosus in 100 cone beam computed tomography examinations. Oral Maxillofac Surg 2015;19:49–53.
19. Gurler G, Delilbasi C, Ogut EE, Aydin K, Sakul U. Evaluation of the morphology of the canalis sinuosus using cone-beam computed tomography in patients with maxillary impacted canines. Imaging Sci Dent 2017;47:69–74.
20. Liang X, Jacobs R, Corpas LS, Semal P, Lambrichts I. Chronologic and geographic variability of neurovascular structures in the human mandible. Forensic Sci Int 2009;190:24–32.
21. Machado VC, Chrcanovic BR, Felippe MB, Manhães Júnior LR, de Carvalho PS. Assessment of accessory canals of the canalis sinuosus: A study of 1000 cone beam computed tomography examinations. Int J Oral Maxillofac Surg 2016;45:1586–1591.
22. Aoki R, Massuda M, Zenni LTV, Fernandes KS. Canalis sinuosus: Anatomical variation or structure? Surg Radiol Anat 2020;42:69–74.