Evaluation of the Morphology of Accessory Canals of the Canalis Sinuosus via Cone-Beam Computed Tomography

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Abstract

Purpose

This study aims to assess the presence of accessory canal (AC) associated with canalis sinuous (CS), describing their frequency, lateralization, location, direction and measurements in cone beam computed tomography (CBCT).

Methods

Axial, coronal, sagittal, and cross-sectional reconstructions were analyzed in 248 CBCT images and the presence of CS, the presence of AC associated with CS, the lateralization, localization and direction course of AC associated with CS was evaluated. CS diameter, AC diameter, distance between nasal cavity floor and CS (M1), CS and the buccal cortical bone (M2) and CS and the alveolar ridge (M3) was measured.

Results

CS dedected in all CBCT scans as bilaterally. The prevalence of AC associated with CS was 35.5%. There was a significant difference between dental status and presence of AC associated with CS. There was a significant difference between gender, dental status, and lateralization of AC associated with CS. While M1 was greater in male patients than females, M3 was greater in female patients. M2 and M3 was greater in younger patients.

Conclusion

Clinicians performing surgical procedures should keep in mind that anatomical variations of the vascular nerve bundle may be seen. M1, M2, and M3 measurements can be affected by gender, age, and dental status.

Introduction

While the anterior maxilla is considered a safe area for surgical procedures, surgeons must pay close attention to the presence of neurovascular structures during operations [1]. Several surgical procedures (such as cyst or tumor operations, removal of supernumerary or impacted canine teeth, orthognathic, periodontal or endodontic surgery, and implant placement) can be conducted in the anterior maxilla [2–5]. Although the most striking anatomical formation in this region is the nasopalatine canal, insufficient evaluation of the canalis sinuous (CS), which is a variation of the anterior superior alveolar nerve, is one of the reasons for failure in surgical procedures [6].

CS was first described by Jones as an intraosseous canal with a diameter of approximately 2 mm, running laterally to the nasal cavity, through which nerves and blood vessels departing from the infraorbital nerve pass through the posterior part of the infraorbital foramen. In the following years, the CS was defined as an anatomical structure in which neurovascular bundles such as the alveolar superior anterior nerve and artery are located [7]. The branches of the CS ending at the floor of the nasal cavity and reaching the level of the maxillary anterior teeth are defined as variations of this structure [3].

Conventional periapical radiographs and orthopantomography are usually used in routine dental procedures; however, these devices are not sufficient to diagnose accessory channels due to low image quality, magnifications, distortions, and superimpositions [8]. Failure to identify CS with conventional imaging methods increases the risk of complications in surgical interventions for the maxillary anterior region. Paraesthesia and bleeding complications have been reported in patients in CS-related implant applications in the literature. In addition, case reports mimicking periapical lesion and root resorption in maxillary anterior teeth are presented. Therefore, it is important that CS can be identified radiographically [9]. Cone-beam computed tomography (CBCT) makes it easier to diagnose these anatomical structures due to the high resolution, cross-sectional view advantages [10].

This study aims to assess the presence of accessory canal (AC) associated with CS, describing their frequency, lateralization, location, direction, and measurements in CBCT scans.

Material And Methods

This retrospective study was approved by the Ethics Committee of the Medical School of University and the study was carried out by the ethical rules of the Declaration of Helsinki (The ethics approval number was KAEK-473). Written consent was signed by all individuals before taking the CBCT.

Data Collection

The study material was selected from the archives of the University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology. CBCT records of patients, who presented between February 2020 and January 2021 for different reasons, were assessed and 516 CBCT images of patients over 18 years of age, in which CS entered the imaging field, were reached. The following exclusion criteria were used to determine the sample size and total of 248 CBCT images included in the study: (1) CBCT images of the patients with congenital disorders, (2) CBCT images suggesting trauma, (3) CBCT images suggesting surgical history except for central incisors extraction, (4) CBCT images with pathological disorders (such as cyst or tumor), (5) CBCT images with impacted canine or supernumerary teeth in the anterior maxilla and (6) CBCT images with technical artifacts.

CBCT images were divided into two groups based on age (<49 years and ≥ 49 years) and dental status in the anterior maxilla (group 1: both maxillary central incisors present and group 2: one or two maxillary central incisor absent).

Images

CBCT images were obtained with the Vera view X800 CBCT device (J. Morita Mfg. Corp, Kyoto, Japan) by the same X-ray technician by the manufacturer's instructions (320 μ m; 4.8 mA; 99 kVp and 17.9 sn for 15x 15x 51.2 field of view and 320 μ m; 4.8 mA; 99 kVp and 35.8 sn for 15x 15x 13.9 field of view). Scans were analyzed using i-Dixel (Version 2.3.6.1 J Morita Mfg. Corp, Kyoto, Japan) as a viewing software.

All the CBCT images were evaluated by the two investigators, who were dentomaxillofacial radiologists, using the same LED monitor, approximately 40–50 cm away from the monitor. To maximize image quality, the images were evaluated in a dim light room and appropriate tonal adjustments. To avoid fatigue, only ten CBCT images were evaluated per day by the investigators.

The investigators were calibrated by evaluating 20 CBCT images together, and the other images were evaluated separately by the investigators. CBCT images where observers were undecided or could not inter-observer agreement were evaluated by a third investigator (H.T.A) with eight years of experience in dental radiology and a final decision has been made.

Evaluation of CS and AC associated with CS

Axial, coronal, sagittal, and cross-sectional reconstructions were analyzed for every image. While slice thickness of CBCT images was 1 mm in axial, coronal, and sagittal planes, it was 0.5 mm in cross-sectional reconstructions. Suspicious images less than 0.5 mm in diameter in the axial plane were not considered AC [11]. The presence of CS was identified according to previous studies [7,12-14] and AC lateralization associated with CS was classified as the right side, left side, and bilateral. AC localization associated with CS was evaluated according to Olivera Santos et al [13]. The direction course of AC associated with CS was evaluated according to Von Arx et al [4] as curved direction, vertical direction, and Y shaped in the coronal plane. The diameter of CS was measured at the junction with the accessory canal in the sagittal section [5]. The diameter of the AC associated with CS was measured in the axial plane. Measurements of the AC associated with CS were made in cross-sectional reconstruction as follows: (1) distance between nasal cavity floor and CS (M1); (2) distance between the emergence of the CS and the buccal cortical bone edge (M2); and (3) distance between the emergence of the CS and the most prominent point of the crest of the alveolar ridge(Figure 1) [15].

Statistical analysis

Data were statistically analyzed using an SPSS software package (version 23.0, SPSS Chicago, USA). The normality assumption was evaluated using the Shapiro-Wilk method. The homogeneity of variance had been verified through Levene's test. For analysis of between two group differences, the independent samples t-test was applied for data with a normal distribution, and the Mann Whitney U test was used for data not displaying a normal distribution. Pearson chi-square test was used to analyze the difference between categorical variables. Statistical significance was assumed at $p < 0.05$.

Results

The CBCT images of 109 (44%) male and 139 (56%) female patients were included in the study; the age range was between 18–78 years and the mean age was 43.31 ± 14.84 years. There were 145 (58.5%) patients in < 49 years and 103 (41.5%) patients in ≥ 49 years and no significant difference between gender and age ($p = .219$).

There were 209 (84.3%) patients in group 1, and 39 (15.7%) patients in group 2 according to the dental status. There was no significant difference between gender and dental status ($p = .126$), however; there was a significant difference between age and dental status ($p < .001$). One or two maxillary central incisors absence was more common in patients with ≥ 49 years ($n = 35$) than in patients with < 49 years ($n = 4$).

CS dedected in all CBCT scans as bilaterally. The prevalence of AC associated with CS was 35.5% ($n = 89$). While this prevelance 52.8% ($n = 47$) for < 49 years and 47.2% ($n = 42$) for ≥ 49 years, it was 48.3% ($n = 43$) for male patients and 51.7% ($n = 46$) for female patients. In addition this prevelance was 76.4% ($n = 68$) for group 1 and 23.6% ($n = 21$) for group 2. There was no significant difference between age, gender and presence of AC associated with CS ($p = .176$ and $p = .3$; respectively). On the other hand, there was a significant difference between dental status and presence of AC associated with CS ($p = .018$).

A total of 129 AC associated with CS, which were the right side in 26 patients, on the left side in 23 patients, and bilaterally in 40 patients, were detected. Table 1 shows the distribution of lateralization of AC associated with CS according to age, gender, and dental status. While there was no significant difference between age and lateralization of AC associated with CS ($p = .89$), there was a significant difference between gender, dental status, and lateralization of AC associated with CS ($p = .022$ and $p = .036$, respectively).

Table 1

Distrubition of lateralization of accesory canal associated with canalis sinuosus according to age, gender and dental status

		right side (n)	left side (n)	bilateral (n)
age	< 49 years	15	12	42
	≥ 49 years	11	11	38
gender	male	7	13	46
	female	19	10	34
	group 1	22	20	52
dental status	group 2	4	3	28
n: number of accessory canal associated with canalis sinuosus; group 1: both maxillary central incisors present; group 2: one or two maxillary central incisor absent				

AC associated with CS was the most often located in the central incisors region (n = 48, 37.2%) and this followed by canin region (n = 25, 19.4%), lateral incisor region (n = 24, 18.6%), between central and lateral incisors (n = 17, 13.2%) and lateral of incisive foramen (n = 11, 8.5%). AC associated with CS was the least often located in the first premolar region and posterior of the incisive foramen (n = 2, 1.6% for both). AC associated with CS did not determine in the anterior incisive foramen. Table 2 shows the distribution of localization of AC associated with CS according to age, gender, and dental status. There was no significant difference between age, gender, and dental status and localization of AC associated with CS (p = .384, p = .63 and p = .367, respectively).

Table 2

Distrubition of localization of accesory canal associated with canalis sinuosus according to age, gender and dental status

	age		gender		dental status	
	< 49 years	≥ 49 years	male	female	group 1	group 2
central incisors (n)	23	25	21	27	30	18
central- lateral (n)	10	7	12	5	15	2
lateral incisor (n)	16	8	16	8	18	6
canin (n)	15	10	10	15	20	5
first premolar (n)	0	2	0	2	1	1
lateral of IF (n)	4	7	5	6	8	3
posterior of IF (n)	1	1	2	0	2	0
n: number of accessory canal associated with canalis sinuosus; IF: incisive foramen; group 1: both maxillary central incisors present; group 2: one or two maxillary central incisor absent						

While 93 (72.1%) of the direction course of AC associated with CS presented curved direction, 33 (25.6%) was vertical and only 3 (2.3%) was Y shape. Table 3 shows the distribution of direction course of AC associated with CS according to age, gender, and dental status. There was no statistically significant difference between the direction course of AC associated with CS and age, gender, dental status (p = .762, p = .564 and p = .674, respectively).

Table 3

Distrubition of direction course of accesory canal associated with canalis sinuosus according to age, gender and dental status

		curved (n)	vertical (n)	Y shaped (n)
age	< 49 years	51	16	2
	≥ 49 years	42	17	1
gender	male	50	15	1
	female	43	18	2
	group 1	67	24	3
dental status	group 2	26	9	0
n: number of accessory canal associated with canalis sinuosus; group 1: both maxillary central incisors present; group 2: one or two maxillary central incisor absent				

CS diameter did not show difference according to age, gender, dental status and presence of AC associated with CS ($p = .854$, $p = .322$, $p = .273$ and $p = .290$, respectively). Table 4 shows the mean, standard deviation, minimum, maximum of the CS diameter according to age, gender, dental status, and presence of AC associated with CS.

Table 4

The mean, standard deviation, minimum, maximum of the canalis sinousus diameter according to age, gender, dental status and presence of accesory canal associated with canalis sinousus

		mean	SD	min	max	p values
age	< 49 years	1.57	0.52	0.5	3.27	.854
	≥ 49 years	1.6	0.6	0.59	3.77	
gender	male	1.61	0.56	0.59	3.77	.322
	female	1.59	0.55	0.5	3.63	
dental status	group 1	1.59	0.55	0.5	3.63	.273
	group 2	1.54	0.58	0.59	3.77	
AC associated with CS	presence	1.62	0.6	0.5	3.77	.290
	absence	1.56	0.52	0.5	3.63	
AC: accesory canal; CS: canalis sinousus; SD: standard deviation; group 1: both maxillary central incisors present; group 2: one or two maxillary central incisor absent						

AC diameter associated with CS was found between 0.5 mm and 2.53 mm and the mean diameter was $0.98 \pm .035$ mm. While the frequency of AC diameter associated with CS was 39.5% when AC diameter was at least 1 mm, the frequency of AC diameter associated with CS was 60.5% when AC diameter was lower than 1 mm. Table 5 shows the mean values of AC associated with CS diameter, M1, M2, M3 according to age, gender, and dental status. M1 was greater in male patients than females and this difference was significant ($p = .039$). M2 and M3 was greater in < 49 years than ≥ 49 years and in group 1 than group 2 (for M2 $p = .02$ and $p = < .001$, respectively and for M3 $p = .004$ and $p = < .001$, respectively). In addition, M3 was greater in female patients than males ($p = .012$).

Table 5
Mean values of all measurements according to age, gender and dental status

		AC associated with CS diameter	M1	M2	M3
age	< 49 years	0.96	13.32	7.03	9.28
	≥ 49 years	1	13.41	6.21	7.06
	p	.625	.912	.02*	.004*
gender	male	0.95	14.14	6.45	7.39
	female	1	12.55	6.86	9.13
	p	.275	.039*	.246	.012*
dental status	group 1	0.96	13.02	7.2	9.42
	group 2	1.02	14.28	5.17	5.07
	p	.658	.192	< .001*	< .001*
group 1: both maxillary central incisors present; group 2: one or two maxillary central incisor absent; AC: accessory canal; CS: canalis sinousus; M1: distance between nasal cavity floor and canalis sinousus; M2: distance between canalis sinousus and the buccal cortical bone edge; M3: distance between canalis sinousus and the most prominent point of the crest of the alveolar ridge; *: <.05					

Discussion

To prevent complications that may occur after surgical procedures in the maxilla anterior region, it is necessary to define the neurovascular structures in the region [16]. Contact with neurovascular bundles can cause sensory dysfunction, bleeding, or non-implant integration during surgical procedures [9, 17, 18]. It is important to determine the presence of neurovascular bundles of the infraorbital canal and the possibility of ACs must be detected before the surgical procedures. CS is one of these neurovascular bundles and is confused with an apical pathology on the upper canine [5].

Anatomical structures cannot be visualized on conventional radiographs due to superpositions. For this reason, CBCT has gained importance for three-dimensional imaging of the region before surgical procedures [19, 20]. In addition, CBCT provides more details and uses lower doses of radiation compared

with computed tomography, permits linear and angular measurements, and allows for multiplanar reconstruction of images [15]. Because of these advantages, CBCT was used to evaluate CS in the current study. The slice thickness of CBCT scans can be affected the detection of the anatomical or other structures and can be reduced artifacts [21]. The current study' slice thickness was 1 mm such as Anatoly et al. [22] in axial, coronal, and sagittal planes.

The high incidence of CS in the literature (99.3% for Anatoly et al [22], 87.5% for Wanzeler et al [5], 100% for Ghandourah et al [11] and 100% for Gürlür et al [1] suggests to the authors that this formation is an anatomical structure, not a variation of the superior alveolar nerve. The results of the current study also support this situation. CS was detected bilaterally in all CBCT scans. On the other hand, CS can be associated with AC in the anterior maxilla. AC associated with CS is a common variation, which is clear when the canal has an extension to the alveolar ridge region [23]. The prevalence of AC associated with CS was found as 35.5% in the current study. This result is lower than Ghandourah et al [11] (67.6%), Aoki et al [24] (66.5%), Orhan et al [25] (70.8%), Machado et al [3] (51.7%), and von Arx et al [4] (56.7%) and it is similar to Shan et al [26] (36.9%) and Tomrukçu et al [8] (34.66%). In addition, Olivera-Santos et al [13] found that 14 of their samples had a direct extension with the CS. These differences in prevalence can be caused by the AC diameter considered in the axial plane, different voxel sizes, and different exclusion criteria. Some studies have only considered CS larger than 1 cm in diameter [4, 13, 26]. Since cases of severe hemorrhage associated with AC with a diameter of < 1 mm during dental implant placement have been reported in the literature [27, 28] in the current study, the limit of AC diameter was accepted as 0.5 mm. In addition, voxel size was 320 µm in the current study.

Some studies [4, 25] reported an increasing frequency with age, although no significant difference was found. In the current study, the frequency was found to be higher in the younger patient group (< 49 years). However, this was not significant and this result may have been coincidental. While Ghandourah et al [11] found a difference between the prevalence of AC and age (in the adult group), no such difference was found in the present study, consistent with the literature [3, 4, 24].

When gender was taken into consideration, AC associated with CS was common in males than females in literature. While this difference was significant in some studies [3, 8, 24] others didn't [1, 4]. The current study didn't reveal such a difference and on the contrary female patients had slightly more common AC associated with CS than males; however, this difference didn't significant. Anatoly et al [22] showed a statistically higher prevalence in females ($p < .001$). In addition, there was a significant difference between dental status and the presence of AC associated with CS. AC associated with CS was more common in group 1 than group 2 ($p = .018$). This situation can result from the small patient number in group 2 or atrophy of the AC may be considered with tooth loss and this condition may be a separate issue to be investigated.

According to Manhas Junior et al [15] AC associated with CS is more common on the left side. The current study showed the most common lateralization of AC was bilateral ($n = 40$). While the current study showed a significant difference between lateralization of AC associated with CS and gender and

dental status, there was no difference between lateralization of AC associated with CS and age. Among the referenced studies no other studies are investigating this difference.

AC associated with CS is more prevalent in the incisor and canine region near the palate [1, 4, 11, 15, 25], however, it can have different locations [5, 13, 22, 26]. AC associated with CS was the most often located in the region of the central incisors at the current study such as Aoki et al [24] and Von Arx et al [4]. On the other hand, Manches Junior et al [15] found the most often location as beside the incisive foramen. The most commonly seen direction course of AC associated with CS in literature was curved and this followed by vertical and Y shaped [4, 8], similar to the current study. There was no significant difference between age, gender, dental status, and localization of AC and direction course of AC associated with CS at the current study.

There are no exact data that describe the mean diameter of CS. While CS diameter is lower than the incisive foramen diameter [20] this structure must not be ignored during surgical procedures [5]. CS diameter can be measured at the bifurcation and in its terminal portion. Wanzelet et al⁵ showed that the diameter of CS is similar in both these portions. Gurler et al and Shan et al [1, 26] found CS diameter higher in males than females ($p = .001$ and $p < .001$, respectively). In the current study, CS diameter was measured at the bifurcation portion and did not show a difference according to age, gender, dental status, and presence of AC associated with CS.

The diameter of AC was reported between 1.1 mm and 1.31mm in literature [3, 4, 8, 13, 26, 29]. The mean diameter was slightly lower ($0.98 \pm .035$ mm) in the current study. While the current study showed that when AC diameter lower than 1 mm the frequency of AC diameter associated with CS was 60.5%, Aoki et al [24] found this frequency as 96.6%, and Machado et al [3] found as 80%. The current study showed there was no significant difference between AC diameter associated with CS and gender, age, and dental status. While this result is similar to Aoki et al [24] in gender, it contradicts Shan et al [26] and Tomrukçu et al [8]. They found that males were found to be significantly higher AC diameter associated with CS than females. In addition, Aoki et al [24], Machado et al [3], Tomrukçu et al [8] didn't find a significant difference between AC diameter associated with CS and age, similar with the current study.

While M1 and M3 were affected by gender, M2 didn't affect the current study. Wanzeler et al [5] found to be greater in males than females the distance between CS' terminal portion and the region of the alveolar ridge. Oliveira Santos et al [13] concluded that males can have different bone density, size, or shape from females. Although M1 was greater in male patients than females ($p = .039$), M3 was greater in female patients than males ($p = .012$) in the current study. While these results are similar to Tomrukçu et al [8] in M3 ($p = .009$) and M2 ($p = .541$), they did not find a difference between M1 and gender ($p = .548$).

The alveolar bone is exposed to morphological changes over time. When age is taken into consideration, M2 and M3 were greater in young patients in the current study ($p = < .001$ for both). While Tomrukçu et al⁸ found a significant difference between M1 and M2 and age ($p = .001$ and ($p = .000$, respectively), such a difference didn't find in M3 ($p = .842$). The inconsistency of the results obtained in both studies suggests

that studies on the measurements of the AC associated with CS are insufficient. In addition, the current study shows that missing teeth reduces M2 and M3 values (Table 5). This result is not surprising given that missing teeth can cause alveolar bone loss.

Clinicians performing surgical procedures should keep in mind that anatomical variations of the vascular nerve bundle may be seen. AC diameter associated with CS is one of these variations, and many clinicians are unaware of its presence and location. CS was detected in all CBCT scans as bilaterally and the prevalence of AC associated with CS was 35.5% at the current study. In addition lateralization of AC associated with CS, M1, M2, and M3 measurements can be affected by gender, age, and dental status.

Declarations

Funding

None to declare.

Competing interests

None to declare.

Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was obtained from the Institutional Review Board of Akdeniz University, according to protocol number 70904504/453.

Patient consent

There were no patients in the study.

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Figures

Figure 1

Measurements of the accessory canal associated with canalis sinuosus