Assessment of canalis sinuosus, rare anatomical structure using cone-beam computed tomography: A prospective study

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ABSTRACT

Objectives: This prospective study was performed with cone-beam computed tomography (CBCT) images for evaluating canalis sinuosus (CS), determine its location and diameter in relation to gender, age, and distances from important structures, including floor of nasal cavity, incisive foramen, edge of buccal cortical bone, and palatal cortical bone.

Material and Methods: The scans of 650 patients in total were included in this prospective analysis. Gender, age, the position of the CS, its presence or absence, diameter, and its location in reference to the adjacent teeth were the factors that were noted.

Results: The study had 301 female participants and 349 male participants, with a mean age of 42.19. Compared to females, males had a statistically higher frequency of CS. Higher age groups showed a higher presence of CS in comparison to the other age groups. The mean distances of these parameters on the left and right side did not differ significantly. Nonetheless, the distance on both sides between CS and nasal cavity floor for males and females, as well as the diameter and border of buccal-palatal cortical bone on the right side, were statistically significant different. On the left side, both genders demonstrated significance in buccal cortical margin and nasal cavity floor. IIn addition, in females, the diameter of the CS on the right and left sides differed on average. The associations between age and number of CS, CS diameter, and number of CS versus sex were all extremely weak. Overall, the study findings showed that CS is a typical anatomical feature in anterior maxillary region, irrespective of age, or gender.

Conclusion: The bony canal, CS is an obscure feature located in the frontal region of the maxilla. Surgeons can avoid complications by being aware of the auxiliary canals derived from this structure. With the use of CBCT, it is now feasible to examine the course of CS as it passes through the maxillary sinus's anterolateral wall with better radiological accuracy has already been documented.

Keywords: Canalis sinuosus, Anatomical variation, Cone-beam computed tomography, Infraorbital nerve, Anterior superior alveolar nerve

INTRODUCTION

The midface's skin and mucosa are supplied by maxillary nerve, which is the second division of trigeminal nerve and gives rise to infraorbital nerve. It enters the face through infraorbital foramen and divides into three alveolar proximal branches (anterior, middle, and posterior

superior alveolar nerves) and four distal branches (inferior palpebral, external nasal, internal nasal, and superior labial).[1-4] Soft tissues, canines, and incisors are all served by anterior superior alveolar (ASA) branch.[5] Another significant anatomical feature in premaxillary region is the nasopalatine canal. The nasopalatine arteries and nerves supply this region, distributing to the anterior teeth and soft tissues.[3] In this area, there are several auxiliary foramina that may be mistaken for apical diseases due to their variations in size and morphological characteristics.[6]

In 1939, Jones published the first account of canalis sinuosus (CS) as one of the area's auxiliary canals. The name originated from the double curvature of the structure. In Jones' original description, the CS is described as a neurovascular bundle that goes through a convoluted bony channel lateral to the nasal cavity, roughly 2 mm in diameter, and starts from posterior portion of the infraorbital foramen.[2] Its location and anatomical structure have been thoroughly documented by various other authors. Starting around 25 mm behind the infraorbital foramen, channel descends to the orbital floor, shifts medially to maxillary sinus anterior wall, and then continues to anterior nasal aperture. In canine region, dental plexus is formed by the neurovascular branches of CS. Inside the CS, the ASA nerve innervates canine and incisor areas as well as the surrounding soft tissues.[7-10]

Of all studies so far, 52.1–88% have the CS identified.[11-15] For this reason, a number of studies have proposed that the CS could be regarded as an anatomical structure as opposed to merely an anatomical variation.[8-14] However, even after 81 years of its initial description, dental practitioners' still lack sufficient knowledge about the CS.[2] Cone-beam computed tomography (CBCT) is the method typically used to examine CS. Unlike helical computed tomography (CT), this method uses lower radiation doses while providing greater detail. In addition, CBCT allows for multiplanar image reconstruction, as well as linear and angular measurements, significantly reduces picture overlap.[16]

This research aims to evaluate and identify the position and diameter of the CS, accounting for variables such as age, gender, and distance from important structures such as the incisive foramen, nasal cavity floor, buccal cortical bone edge, and palatal cortical bone.

MATERIAL AND METHODS

Data collection

CBCT images from 650 participants who satisfied the inclusion criteria were included in the current investigation. From the image files, the patients' identities were deleted. The study's inclusion criteria included CBCT scans from consenting patients and maxilla CBCT images of patients receiving implants. Exclusion criteria that were applied were

as follows: (1) imaging artifacts that would make it difficult to evaluate important structures; (2) images with implants, grafted alveolar ridges, or missing teeth; (3) presence of additional or retained deciduous teeth in the anterior maxilla; (4) any pathological lesion in the anterior maxillary region; (5) patients who have undergone previous maxillary surgery, including orthognathic surgery; and (6) CBCT scans with poor acquisition quality in voxels larger than 0.20 mm within a 40-s examination window.

Procedures

Anatomical description of the CS, as found in the literature, was used to identify it on the CBCT images. Bony canals were found in the anterior maxilla and were observed to point clearly upward toward the CS. The assessed parameters taken into account includes: either the presence or absence of the CS, diameter, position, distance between CS and nasal cavity floor, incisive foramen, buccal cortical bone edge, and palatal cortical bone in relation to age and gender. The diameter of each canal was measured halfway along its course, which is the distance from its beginning at the CS to its terminus. Figure 1 displays the morphometrics of the CS. The reconstructions of the axial, coronal, sagittal, panoramic, and cross-sectional views were examined for each instance. Measurements of the palatine aperture on coronal and cross-sectional images of the extra canal were used to calculate diameters. Two evaluations of CS locations were performed by the same observer, at least 2 months apart.

Statistical analysis

Descriptive statistics are used to analyze the data. To evaluate differences for various parameters among males and females, the χ^2 test and Student's t-test were employed. Depending on whether the data were normal, Mann–Whitney test was additionally applied where necessary. To ascertain the relationship between quantity of CS and sex, Spearman's correlation was employed. The association between age and other two additional variables such as the diameter of CS and number of CS was evaluated using Pearson's correlation and linear regression. Using Cohen's kappa, intraobserver agreement for categorical data was assessed. An established threshold for significance was set at $P < 0.05$. Version 20.0 of IBM SPSS Statistics (IBM Corp., Armonk, NY, USA) was used to analyze all of the data.

RESULTS

The study comprised 650 patients with a mean age of 42.19. Males were the predominant gender with a count of 349, while females had a count of 301. Figures 2-4 represent the gender presentation, presence of CS, and its laterality. In Table 1, the ages of the subjects in the CS groups (present/absent) were
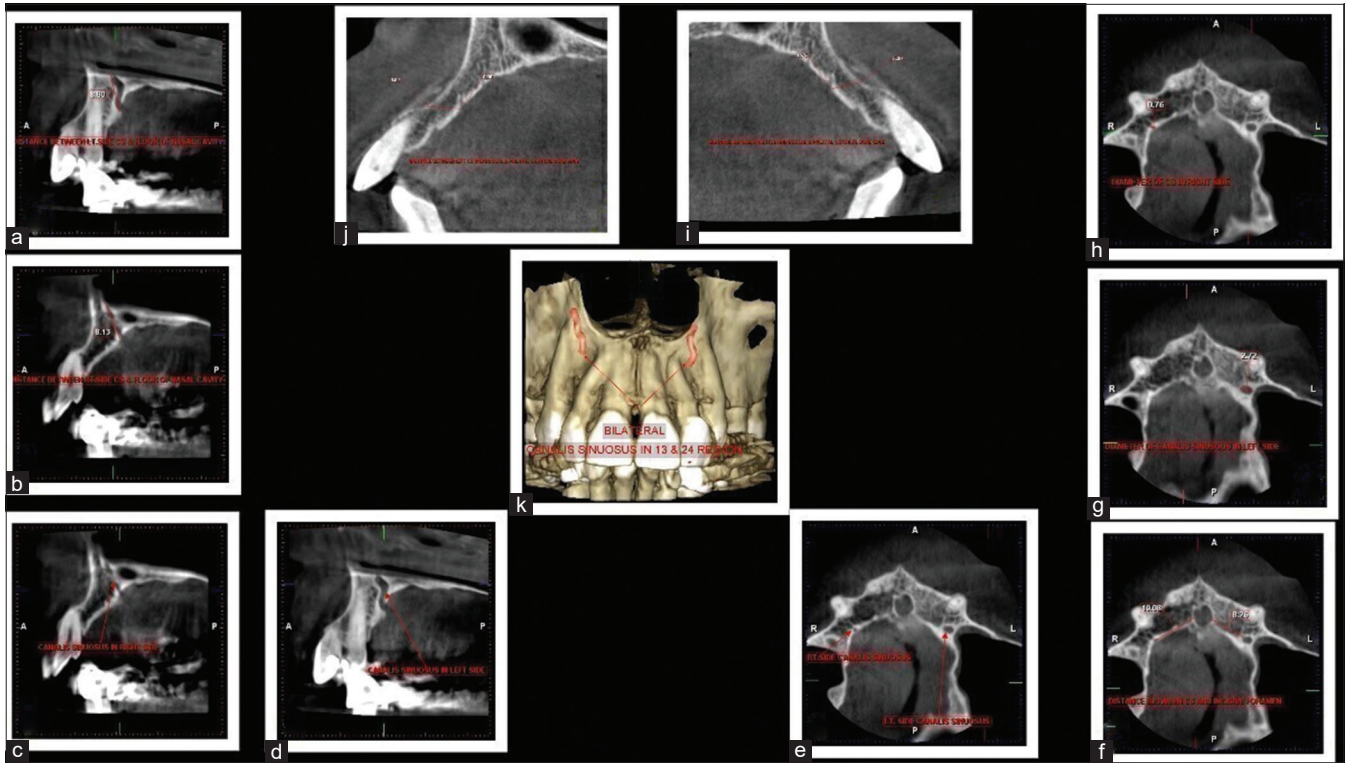
Figure 1: Distance between left side canalis sinuosus (CS) and floor of nasal cavity. (a) Distance between the right side CS and floor of nasal cavity. (b) CS on the right side. (c) CS on the left side. Red arrows indicates the presence of canalis sinuosus on the right side and left side in the sagital sections. (d) Axial section shows presence of CS. Red arrows indicating the presence of canalis sinuosus on the right and left side in the sagital sections. (e) Distance between CS and incisive foramen. Red arrows indicates the presence of canalis sinuosus on the right and left side in axial view. (f) Diameter of CS in the left side. (g) Diameter of CS on the right side. (h) Distance between the right side CS and buccal and palatal cortical bone edge. (i) Distance between left side CS and buccal and palatal cortical bone edge. (j) 3D representation of CS. (k) Red arrows shows bilateral presence of canalis sinuous in 3D view.

compared. The CS present group's mean age was marginally higher than the other groups, with $P = 0.0032$ indicating a statistically significant difference in mean age between two groups. Similarly, the gender of the subjects was compared between the groups. It was found presence of canalis sinuous in 59% males and 48 % females. CS was absent in 40% males and 51 % females. This indicates an association between the two variables (gender and CS) with $P = 0.003$.

The right and left sides were compared with respect to a number of parameters, including CS diameter, distance between it and floor of the nasal cavity, incisive foramen, edges of the buccal cortical bone, and palatal cortical bone. There was no discernible difference in the mean distances of these metrics on the left and right sides [Tables 2 and 3]. Parameters such as the distance between the CS and nasal cavity floor, incisive foramen, buccal cortical bony edges, palatal cortical bone, and the diameter of the CS were compared between males and females for both right and left sides. Results showed that the diameter of the right side CS and distance between it and the nasal cavity floor, along with the margin of buccal-palatal cortical bone, were statistically significant for both
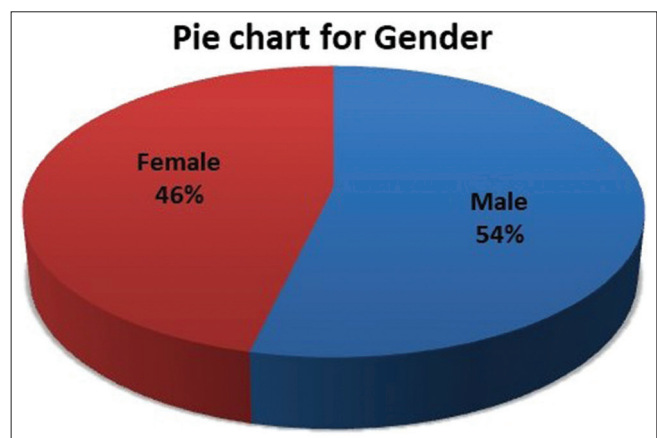

Figure 2: Gender presentation of the study.

genders. Significant for both genders were the nasal cavity floor and buccal cortical margins on the left side [Table 4].

In Figures 5 and 6, the different parameters such as distance between CS and nasal cavity floor, incisive foramen, buccal cortical bony edges, palatal cortical bone, and the diameter

of CS are compared between the right and left sides for each gender. With $P < 0.05$, there was a significant mean difference in the diameter of CS between the right and left sides of females. However, none of the other factors show any significant changes ($P > 0.05$). Figure 7 compared gender of the patients with the laterality of the CS and found an association between the two variables. This association was statistically proven with $P < 0.05$.

DISCUSSION

Clinicians' awareness of anatomical variances improves prognosis and reduces the likelihood of complications.[5] The anterior maxilla contains significant neurovascular bundles.
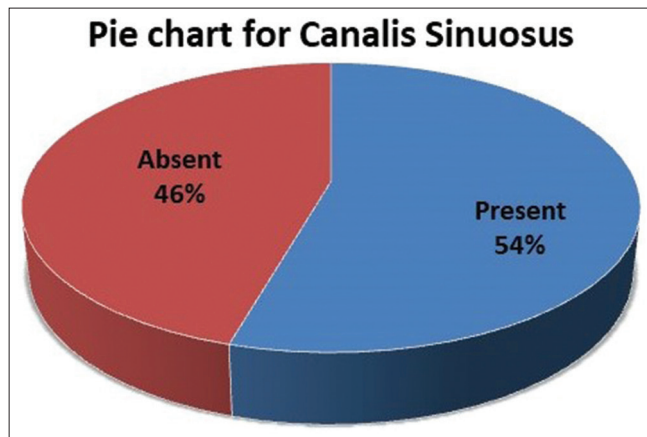

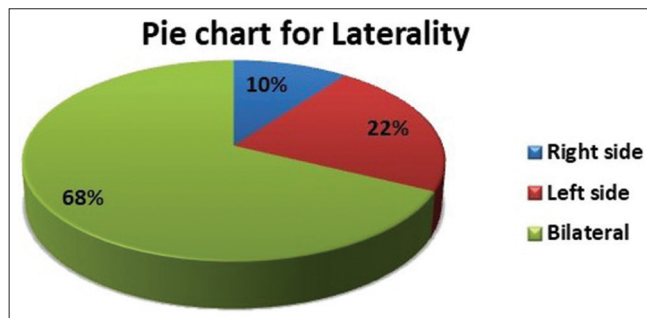**Figure 3:** Presence of canalis sinuosus.

Figure 4: Laterality presence of canalis sinuosus.

Table 1: Descriptive statistics for presence of canalis sinuosus.

Parameters	Canalis sinuosus		P-value
	Present n (%) n=354	**Absent** n (%) n=296	
Age in years:			
Mean (SD)	43.81 (15.46)	40.27 (17.69)	0.0032^M (S)
Gender			
Male	209 (59.89)	140 (40.11)	0.003^C (S)
Female	145 (48.17)	156 (51.83)	

M: Mann–Whitney U-test, C: Chi-square test, S: Significant (P<0.05), SD: Standard deviation, n: Number

Surgical procedures may result in injury to these structures, leading to hemorrhaging; and sensory abnormalities (such as hyperesthesia, paresthesia, or discomfort). These injuries can appear as lesions, which may leads to diagnostic confusion, which was once reported by Shah *et al.* explaining the incorrect diagnosis of an accessory branch of the CS on periapical radiography as external root resorption.[6] It can be difficult to visualize the auxiliary branches of the CS using conventional radiography techniques, as these accessory canals often have a diameter of <1 mm. Moreover, the irregular course and porous cortical layers of the CS have been identified as a diagnostic challenge for traditional radiography techniques. In clinical practice, the variations of the CS and its auxiliary canals are not well-known. However, with the increasing use of 3D imaging in clinical practice, these variations are getting attention.

Out of 650 patients, CS was found to be more common in males (59.89%) than females (48.17%). Older age groups showed a higher prevalence of CS (15.46 %) compared to other groups. The results of a study by Machado *et al.*,[13] which also found a statistically significant difference in the prevalence of CS with male dominance, are consistent with these findings.

Manhaes Junior *et al.*[16] showed prevalence of 5% CS which is very low when compared to 54% found in our study. This could be due to various ethnic populations found in different parts of the country. In our investigation, CS had an average diameter of <1 mm. The mean distances of CS to various parameters were not substantially different on the left and right sides ($P > 0.05$). In addition, the study looked at gender-stratified distances between CS and other anatomical landmarks on both sides. For both males and females, there was statistical significance in the distance measured between CS and nasal cavity floor, diameter of CS on the right side, and margins of buccal-palatal cortical bone. For both genders, the nasal cavity floor and buccal cortical margin were substantial on the left side.

Manhaes Junior *et al.*[16] measured the distance between CS and anterior ridge crest (ARC), buccal cortical bone (BCB), and nasal cavity floor (NCF) at each study site and reported that, left-only distance determined by CS and BCB in female group differed significantly.

For every measurement, there were no differences between sides in male group. The CS-to-ARC and BCB distances were comparatively dissimilar, with a leftward bias in the mixed group. The lengths from CS to NCF on the right and left sides did not differ significantly in any groups.[17,18] When these parameters were compared separately in each gender, no statistical differences were found. Correlations were made between age and various measurements, but no significant correlation was found between any of the parameters and with age ($P > 0.05$). This finding is consistent with the previous studies by de Oliveira-Santos *et al.* and von Arx and Lozanoff, which also did not find any appreciable differences

Table 2: Position of canalis sinuosus distribution.

Position	Laterality		
	Right side n (%)	Left side n (%)	Bilateral n (%)
In central incisor region	5 (13.89)	13 (16.67)	96 (20)
Between central incisor and lateral incisor	8 (22.22)	9 (11.54)	73 (15.2)
Lateral incisor region	7 (19.44)	24 (30.77)	174 (36.2)
Between lateral incisor and canine	1 (2.78)	2 (2.56)	10 (2.1)
Canine region	6 (16.67)	10 (12.82)	36 (7.5)
First premolar region	2 (5.56)	4 (5.13)	16 (3.33)
Lateral to incisive foramen	3 (8.33)	3 (3.85)	13 (2.7)
Anterior to incisive foramen	4 (11.11)	13 (16.67)	62 (12.9)
Total	36 (100)	78 (100)	480 (100)*

*480 indicate both right and left side of subjects, n: Number

Table 3: Comparison of various measurements on the right and left sides.

Distance	Right side (n=276) Mean (SD)	Left side (n=318) Mean (SD)	P-value
Nasal cavity floor	15.86 (3.14)	16.26 (3.33)	0.1346^T
Incisive foramen	4.09 (2.98)	4.25 (3.1)	0.5689^M
Buccal cortical bone edge	7.81 (1.79)	7.94 (1.77)	0.2736^M
Palatal cortical bone edge	2.33 (1.57)	2.13 (1.32)	0.2647^M
Diameter of CS	0.81 (0.21)	0.83 (0.26)	0.3894^M

T: Two sample T test, M: Mann Whitney U test, P>0.05. SD: Standard deviation. CS: Canalis sinuosus, n: Number of participants

Figure 5: Comparison of various measurements on the right side for each gender. (CS: Canalis Sinuosus).
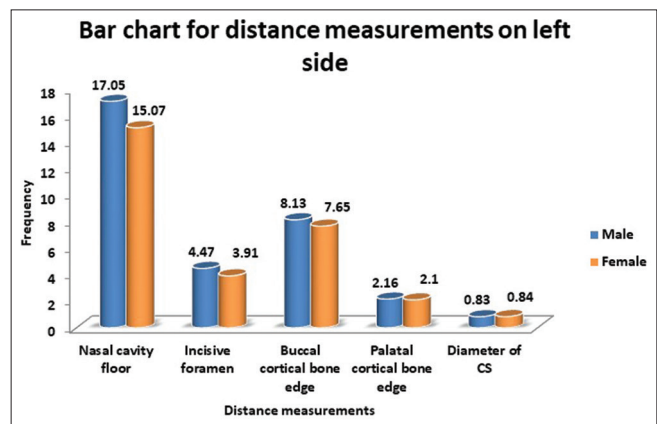
Figure 6: Comparison of various measurements on the left side for each gender.

in age or gender.[7,9] The subjects' mean ages were found to be equal in both groups when their ages were compared to the laterality of the CS, and there was no difference between their means ($P > 0.05$).

Our study also examined the lateralization of CS based on gender distribution and found a significant association between the two variables. According to the latest investigation, bilateral lateralization of CS was the most prevalent (78%) whereas the study conducted by Velpula et al.[19] showed that only 9.5 % this could be attributed towards ethnic variations. A study by Wanzeler et al. found a significant variance in the lateralization of CS and gender. Furthermore, it was found that the placement of the CS on the left and right sides correlates with age. On the right side, there was a weak negative correlation and on the left, a weak positive association. These connections, however, did not reach any statistical significance ($P > 0.05$).[8,10] Surgeons contemplating interventions in locations where the CS is present should be cognizant of its presence to minimize the potential of iatrogenic damage to the patient. Acknowledging it as a component of their pre-surgical workup can prove beneficial for them. Well-established standards state that before performing radiological imaging, one must weigh the expected information to be obtained against the ionizing radiation.
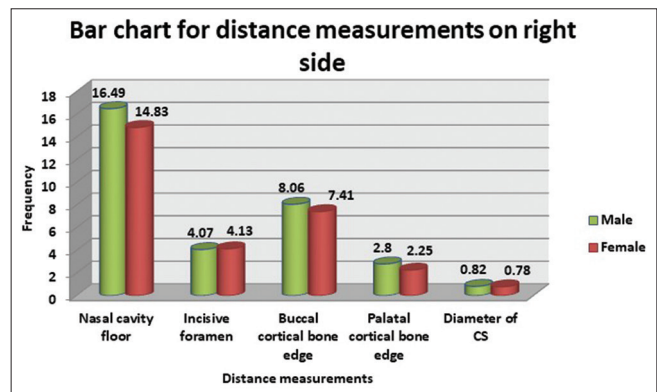
The European Association of Osseointegration recommendations state that if a clinical examination and conventional radiography provides sufficient information, then CBCT and other further imaging is not required.[20] However, as noted in a recent publication by Shelley et al., the American Academy Of Oral and Maxillofacial Radiology endorses CBCT imaging for

Table 4: Comparison of various measurements for gender.

Distance	Male	Female	P-value
	Mean (SD)	Mean (SD)	
Right side	n=171	n=105	
Nasal cavity floor	16.49 (3.05)	14.83 (3.01)	**<0.0001**[T]
Incisive foramen	4.07 (2.93)	4.13 (3.08)	0.8704[M]
Buccal cortical bone edge	8.06 (1.87)	7.41 (1.58)	**0.0021**[M]
Palatal cortical bone edge	2.8 (1.54)	2.25 (1.61)	**0.0454**[M]
Diameter of CS	0.82 (0.22)	0.78 (0.18)	**0.0314**[M]
Left side	n=191	n=127	
Nasal cavity floor	17.05 (3.36)	15.07 (2.91)	**<0.0001**[T]
Incisive foramen	4.47 (3.24)	3.91 (2.76)	0.1872[M]
Buccal cortical bone edge	8.13 (1.81)	7.65 (1.67)	**0.0034**[M]
Palatal cortical bone edge	2.16 (1.33)	2.1 (1.32)	0.4964[M]
Diameter of CS	0.83 (0.26)	0.84 (0.26)	0.5662[M]

T: Two sample T test, M: Mann Whitney U test. Bolded *P* values are significant *P<0.05. SD: Standard deviation, CS: Canalis sinuosus, *n*: Number
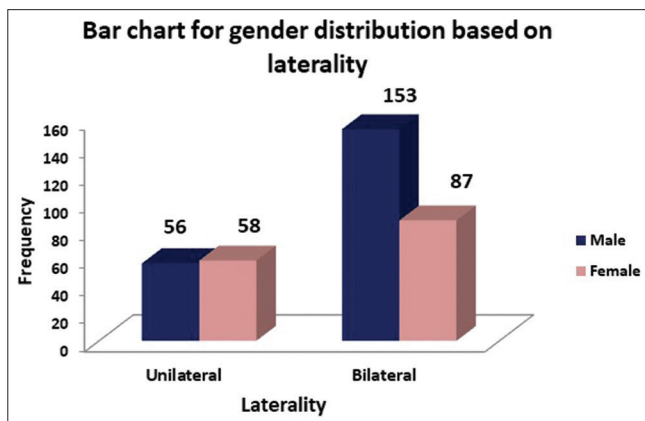
Figure 7: Comparison of gender and laterality.

evaluations of all implant sites.[21,22] Future advancements in CBCT technology, which are anticipated to lower radiation dosages, enhance computer algorithms, and enable smaller scan windows, may cause these conflicting improvements to converge. Considering this uncertainty, it is recommended that the anterior maxilla's CBCT be accessible and that the CS be actively sought out and recognized for an appropriate planning. Clinicians should also consider the possibility of impingement on the CS in cases when surgical operations performed on the anterior maxillary regions result in unanticipated unfavorable effects.[20-22]

CONCLUSION

Regardless of age or gender, CS is a common anatomical structure which is relevant for surgery in the area due to its great occurrence. Recognizing these distinct anatomical variations may aid surgeons in avoiding nerve injury during surgery. In comparison to females, males had a statistically higher frequency of CS. The age distribution showed a statistically significant difference. Anterior maxillary, or palatal region, is the most common location for the end of the accessory canal trajectory. The age and number of CS, age and diameter of CS, and number of CS and sex were found to have very little correlations. With a 100% CBCT identification rate for the CS in the current investigation, CBCT is the recommended investigative method for precisely identifying the CS. Significant variations between the left- and right-sided scans were observed throughout the CS. This information could be useful to physicians planning treatments in the CS area, potentially reducing iatrogenic neurovascular problems.

Ethical approval

The research/study approved by the Institutional Review Board at Sree Balaji Dental College and Hospital, Bharath University, Chennai, Tamil Nadu, India, number SBDCH/IEC/12/2021/25, dated 01.02.2021.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation:

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the

writing or editing of the manuscript and no images were manipulated using AI.

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