Introduction

The anterior superior alveolar nerve (ASAN) is a part branch of the infraorbital nerve, which follows an intraosseous path in the canalis sinuosus (CS) to innervate the central and lateral incisors and canines. The ASAN is generally much thicker than the middle and posterior superior alveolar nerves. Canalis sinuosus is a little known structure of the anterior maxilla. The insertion point is anterior to the incisive canal, where the CS shows anatomical variations commonly called accessory canals (ACs) in the anterior palate. This anatomical structure has nerve and blood vessels that leave the infraorbital nerve from the posterior part of the infraorbital foramen and laterally pass through a bone canal approximately 2 mm in diameter next to the nasal cavity. The CS is a branch of the nerve of the infraorbital canal, through which the anterior superior alveolar nerve passes. It follows the lower margin of the nasal aperture and opens to the side of the nasal septum in front of the incisive canal. Subsequently, it bends between the nasal cavity and the maxillary sinus, reaching the premaxilla in the canine and incisor region. The infraorbital nerve is the direct extension of the maxillary nerve and is responsible for the sensitivity of the skin and mucosa of the middle third of the face. In addition, the anastomosis of the ASAN and the greater palatine nerve located in the canalis sinuosus, showing a distribution of the ASAN to the palatine mucosa.

This canal, which is very important for surgical procedures, is relatively unrecognized amongst clinicians unless they confront complications, such as paresthesia or hemorrhage. Additionally, the CS and ASAN have been inadequately described in the surgical and radiological literature and their course has been portrayed as variable in anatomical textbooks. Placement of dental implants, surgical removal of impacted or supernumerary teeth...
It is stated in the literature that anatomical variations in the maxillary bone are rare, and that the majority of these are associated with the nasopalatine canal. It is also important to be aware of other anatomical variations in the maxilla, which ensures success in surgical operations.

In the literature, there are studies evaluating the presence and variations of the CS. Most of these studies were performed using CBCT images. Ghandourah et al. evaluated CS frequency, location and width with 269 CBCT images in two groups of adolescents and adults.

Kurrek et al. dissected 35 human cadavers and evaluated the ASAN by taking images with CBCT. Orhan et al. examined images for the CS presence, accessory canal presence, location and number. Studies evaluating the CS are limited in Turkish population, so further studies are needed in this area.

The research’s null hypotheses was that anatomical variations in the maxillary bone are rare. The aim of this study was to use CBCT to evaluate the prevalence of CS and its variations with regard to age, gender, location, relationship to the impacted canines in a Turkish sample.

Material and Methods

Cone beam computed tomography (CBCT) scans of patients admitted to the Faculty of Dentistry, Oral and Maxillofacial Radiology Department for dental complaints (e.g., a missing tooth, orthodontic or implant planning, or periodontal or temporomandibular disorder) from 2014 to 2019 were reviewed retrospectively. The CBCT images of 673 patients (322 females and 351 males) were assessed. Any canal with about 1 mm diameter in the anterior maxilla region was evaluated with CBCT. The nasopalatine canal was excluded. The Sidexis XG software program (Sirona, Bensheim, Germany) was used to reconstruct and evaluate the projections and these were analyzed with sagittal, coronal and axial sections (Figure 1).
Patients were excluded according to the following criteria; bony lesions in the anterior maxilla region, a history of dentofacial surgery, the presence of artefacts and low-quality imaging of the region of interest. Informed consent was obtained from the patients who participated in the study. The study was approved by the Ethical Committee (the study protocol: 2019/28-10).

Radiographs were taken through a CBCT (Sirona Galileos Comfort Plus- Bensheim, Germany, at 98kV, 6mA, and a voxel size of 0.25 mm). The field of view (FOV) of the images assessed in this study was 15 × 15cm. The Sidexis software was used to convert the original digital imaging and communication in medicine (DICOM) format. The evaluation of the images was performed on the monitor screen (Asus PRO A4310-BB158M All In One, ASUSTeK Computer Inc., Beitou District, Taipei, Taiwan). The data obtained was recorded in the Microsoft Excel program to determine the frequency with regard to age group, gender, presence of CS, location in relation to the adjacent teeth and the impaction of canine teeth.

Two oral and maxillofacial radiologists evaluated the radiological images in a dark, quiet room. The data of 673 patients was analyzed. SPSS 22 for Windows (Statistical Package for Social Sciences IBM, New York, USA) was used for statistical analysis of the results. Comparisons between two groups were made using chi-square tests. Wilcoxon’s matched pairs signed rank test was used to determine intra-examiner reliability and inter-examiner reliability was assessed using the intraclass correlation coefficient (ICC) and the coefficient of variation (CV). Significance was set at p< 0.05. Intra-observer and intra-observer calibration were provided based on anatomical diagnoses from the CBCT images, and were assessed for data reliability. Observers evaluated the same images twice, with an interval of one week between evaluations.

### Results

Our study consisted of images of 673 patients who complied with the criteria. There were 322 female patients (47.84%) and 351 male patients (52.15%). The age of the patients ranged between 14 and 82 years, and the mean ages for the female/male patients were 43.54 years and 45.75 years respectively. Overall, it was found that 8.17% of the patients in this study exhibited AC of CS (n= 55). A total of 62 AC were found in different location in 55 patients. While there was no AC in 618 patients (91.8%) in the study group, the number of patients with one AC was 55 (8.17%), and the number of patients with two AC was seven (1.04%). There was a significant difference between the genders concerning AC of the CS occurrence. The distribution of CS among genders is shown in Table 1.

| Gender | Male | Female | Total |
|--------|------|--------|-------|
| (-) n (%) | 315 (89.7%) | 303 (94.1%) | 618 (91.8%) |
| (+) n (%) | 36 (10.3%) | 19 (5.9%) | 55 (8.2%) |
| n | 351 | 322 | 673 |

(p< 0.05)

Of the patients with AC in this study (n= 55), seven were aged between 14 and 25 years, 11 were between 26 and 35 years, 12 were between 36 and 45 years, and 25 were over 60 years old. There was no statistical relationship between age and AC prevalence (Table 2).

### Table 2. Distribution of CS among age groups

| Age Groups | Male n (%) | Female n (%) | Total n (%) |
|------------|------------|--------------|-------------|
| 14-25      | 4(11.1%)   | 3(15.7%)     | 7(12.7%)    |
| 26-35      | 4(11.1%)   | 7(36.8%)     | 11(20%)     |
| 36-45      | 8(22.2%)   | 4(21.1%)     | 12(21.8%)   |
| 46 +       | 20(55.6%)  | 5(26.4%)     | 25(45.5%)   |

(p> 0.05)

AC was most common in the regions of tooth 12 and tooth 22 followed by the regions of tooth 11 and tooth 23. Moreover AC openings were detected close to the incisive foramen (IF). The distribution of ACs close to the incisive foramen is shown in Table 3.

| Location of CS | n | % |
|----------------|---|---|
| 11             | 7 | 11.29 |
| 11-12          | 3 | 4.84 |
| 12             | 8 | 12.90 |
| 12-13          | 0 | 0.00 |
| 13             | 3 | 4.84 |
| 13-14          | 0 | 0.00 |
| 21             | 4 | 6.45 |
| 21-22          | 6 | 9.68 |
| 22             | 8 | 12.90 |
| 22-23          | 1 | 1.61 |
| 23             | 7 | 11.29 |
| 23-24          | 2 | 3.23 |
| Anterior of IF | 7 | 11.29 |
| Posterior of IF | 2 | 3.23 |
| Right to IF    | 0 | 0.00 |
| Left to IF     | 4 | 6.45 |

IF: Incisive foramen

The greatest number of AC openings was observed anterior to the incisive foramen (n= 7, 11.29%). AC was not found in the regions between tooth 12 and tooth 13 and between tooth 13 and tooth 14; also, it was not found right to the incisive foramen (IF).
AC was found in at least two locations in some patients. Where two ACs were found in the same patient, the locations were: in the region of teeth 22-23 and tooth 23, in the region of tooth 12 and tooth 22, in the region of tooth 12 and teeth 23-24, in the region of tooth 11 and teeth 21-22, the region of tooth 23 and anterior of the IF. Two different patients had the same AC location in the regions of tooth 12 and tooth 22.

The presence of impacted canine teeth was also registered. One canine impaction was found located on the left side. The results showed intra-examiner reliability between the observers (p> 0.05), with the ICCs between the two observers ranging from 0.911 to 0.930. The high ICC and low CV showed that the CBCT assessment process was standardized between observers and that there was high inter-examiner agreement.

Discussion

The anterior maxilla is generally considered an extremely safe surgical area. Therefore, during surgical procedures in this area, surgeons have often only paid attention to the nasopalatine canal or nasal floor. Recently, more awareness has been raised of the thinner neurovascular structures in the anterior maxilla\(^1\). The ASAN is the largest of the superior alveolar nerves and originates from the infraorbital nerve. On the orbital floor, it passes laterally to the infraorbital canal in the CS\(^2\). Recent research has shown bone canals in the anterior maxilla related to CS and these accessory canals generally reach the apices of the anterior teeth\(^2,3,21\). In addition, it has been reported that superimposition of the lower portion of the CS onto the anterior maxillary teeth may mimic periapical lesion\(^5\).

In the literature, cases of severe hemorrhage have been reported associated with an accessory foramen with a diameter of <1 mm during dental implant placement. Volberg et al. presented a case showing trigeminal neuralgia related to damage of the CS after immediate implant placement\(^22\). Therefore, in cases requiring surgical procedures (such as implant placement, impacted tooth surgery), it is important to consider how to optimize preoperative preparation and prevent complications. In addition, careful preoperative imaging analysis of the neurovascular ducts in the jaws should be performed based on macroscopic and microscopic anatomical knowledge\(^19,21\).

Two-dimensional (2D) images, such as panoramic and periapical radiography, provide visualization of limited quality. Due to superimpositions or artefacts, CS is recognized with difficulty. Furthermore, many clinicians identify this structure as a pathology. Cone beam computed tomography (CBCT) is a safe method commonly used in dentistry to obtain three-dimensional images of the jaw. It is especially useful for CS research, as it can provide high resolution images and detailed three-dimensional scans\(^3,23\). Anatoly et al reported that the best visualization for detecting CS was achieved with 0.5 mm and 1 mm slice thickness slices\(^11\).

In 2012 de Oliveira Santos et al.\(^20\) demonstrated that additional palatine foramina at least 1 mm in diameter were found in around 16% of patients of both genders and different age groups. In 2017 Ghandourah et al.\(^13\) assessed the frequency, location and width of ACs of the CS using CBCT. In 2018, Orhan et al.\(^3\) evaluated the presence or absence of CS with regard to age, sex, location in relation to the adjacent teeth and impaction of canine teeth.

In the present study, the age of the patients ranged from 14 to 82 years and the age groups were 14-25 years old, 26-35 years old, 36-45 years old and 46 or more years old. There was no statistical relationship between age or age groups and AC of the CS prevalence. This result is in agreement with the results of research by de Oliveira Santos, Orhan, von Arx and Machado et al.\(^2,3,20,21\).

Studies have shown no statistically significant difference despite the tendency of men to have more ACs than women\(^2,3,13,21\). Although Manhaes Jr et al.\(^16\) and de Oliveira Santos et al.\(^20\) reported that they found 99 females to 82 males and 15 females to 13 males with ACs respectively, they also stated that they did not find any statistical differences. In contrast to the literature, in our study, there was a significant difference between the genders in AC of the CS occurrence, with males showing a higher prevalence than females. This result is in agreement with the research of Tomrukcu et al.\(^24\) and Aoki et al.\(^10\).

In our study, a total of 62 AC of the CS were found in different locations in 55 patients (8.17%). Machado et al.\(^21\) found that frequency of the CS was 52.1%, Manhaes Junior et al.\(^16\) found the frequency of the CS was 36.2%, de Oliveira Santos et al.\(^20\) reported 15.7%, Orhan et al.\(^2\) reported 70.8%, Ghandourah et al.\(^13\) reported 67.6%, von Arx et al.\(^2\) reported 27.8%. These discrepancies may result from differences in voxel size or from selecting different reference values as the channel diameter.

The regions where AC of CS were predominantly observed varies in the literature. Ghandourah et al.\(^13\) reported that ACs were found in the adult group mostly in the region of the central incisors, followed by the left and right lateral incisors and canine regions. In the adolescent group, the area of highest prevalence was the left lateral incisor and canine region\(^13\). Von Arx et al.\(^2\) stated that the area where AC were most frequently found was the palatal region to the central incisors. Orhan et al.\(^3\) stated that CS were most frequently observed in the maxillary inter-central region. Machado et al.\(^21\) stated that the area of greatest prevalence was the palatal side of the anterior maxillary teeth. Manhaes Jr et al.\(^16\) reported that it was beside the incisive foramen. De Oliveira Santos et al.\(^20\) reported that it was in the alveolar process near
the incisors or canines. Sekerci et al.\textsuperscript{25} reported that the accessory canals were located most frequently palatal to the left lateral incisor. Anatoly et al.\textsuperscript{11} reported that CS was most frequently present in the lateral incisor region. Similarly, in our study, AC was most common in the region of the right and left lateral incisors, tooth 12 and tooth 22. In addition, AC openings were most commonly observed anterior to the incisive foramen.

The published literature revealed great variability and differing results in the studies of the CS, highlighting the lack of standardization of the studies, and suggesting that results may depend on the slice thickness of the CBCT. The articles show that CS is an important structure, considering the neurovascular bundle it carries\textsuperscript{8,11}.

The present study has some limitations - a limited number of samples were used for the study. Further studies are needed on larger cohorts in this area.

**Conclusions**

It can be concluded that there is no relationship between the CS location or age group. In addition, it was found that there are significant differences in the frequency of the CS concerning gender. Contrary to popular belief, anatomical variations in the maxillary bone are not rare. It is important to take into consideration the presence of AC of the CS during surgical procedures in the anterior region. Clinicians should recognize these anatomical structures with CBCT before surgical operations, to avoid possible complications and prevent inappropriate treatment and injuries.

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