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ORIGINAL ARTICLE

Assessment of bone channels other than the nasopalatine canal in the anterior maxilla using limited cone beam computed tomography

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Abstract

Purpose The anterior maxilla, sometimes also called premaxilla, is an area frequently requiring surgical interventions. The objective of this observational study was to identify and assess accessory bone channels other than the nasopalatine canal in the anterior maxilla using limited cone beam computed tomography (CBCT).

Methods A total of 176 cases fulfilled the inclusion criteria comprising region of interest, quality of CBCT image, and absence of pathologic lesions or retained teeth. Any bone canal with a minimum diameter of 1.00 mm other than the nasopalatine canal was analyzed regarding size, location, and course, as well as patient gender and age.

Results A total of 67 accessory canals $\geq$1.00 mm were found in 49 patients (27.8 %). A higher frequency of accessory canals was observed in males (33.0 %) than in females (22.7 %) ($p = 0.130$). Accessory canals occurred more frequently in older rather than younger patients ($p = 0.115$). The mean diameter of accessory canals was 1.31 $\pm$ 0.26 mm (range 1.01–2.13 mm). Gender and age did not significantly influence the diameter. Accessory canals were found palatal to all anterior teeth, but most frequently palatal to the central incisors. In 56.7 %, the accessory canals curved superolaterally and communicated with the ipsilateral alveolar extension of the *canalis sinuosus*.

Conclusions The study confirms the presence of bone channels within the anterior maxilla other than the nasopalatine canal. More than half of these accessory bone canals communicated with the *canalis sinuosus*. From a clinical perspective, studies are needed to determine the content of these accessory canals.

Keywords Anterior maxilla · Bone channel · Accessory canal · Nasopalatine canal · *Canalis sinuosus*

Introduction

The anterior maxilla, sometimes also called premaxilla, is an area frequently requiring surgical interventions, e.g., placement of dental implants, surgical removal of impacted or supernumerary teeth, periodontal surgery, endodontic surgery, cyst therapy, and orthognathic surgery [2, 5, 6, 9, 10, 16, 18, 21]. In particular, the increased demand for endosseous dental implants has necessitated a greater appreciation and understanding of surgical techniques in dentistry. Previously, patients were rehabilitated with mucosa- or tooth-borne prostheses whereas in the last three decades, the focus has shifted to implant-borne reconstructions [1, 15]. However, the placement of endosseous implants in the anterior maxilla is often associated with ridge augmentation procedures due to bone resorption after tooth extractions, dento-alveolar trauma, or because of

This retrospective and observational radiographic study complies with the current laws of Switzerland where the study was performed.

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periradicular and periodontal pathology [4]. Such cases require meticulous treatment planning including radiographic assessment of bone anatomy. Limited cone beam computed tomography (CBCT) has become increasingly critical in this regard [24]. Current CBCT technologies allow a precise three-dimensional evaluation of the bone quality and quantity of the maxilla, and finer details such as neurovascular bone channels become radiographically visible.

The most prominent anatomical structure within the anterior maxilla is the nasopalatine canal [3, 13]. This canal carries the nasopalatine nerves, arteries, and veins from the anteromedial region of the nasal cavities to the primary palate area through the incisive foramen [12, 20]. Recent publications have drawn attention to radiographically visible accessory canals that may carry neurovascular structures to the anterior maxilla [7, 14]. Various terms have been applied to these canals including lateral incisive canal, neurovascular variations in the anterior palate, or accessory canals [7, 14, 23]. Common to these anatomical variants is their communication with the *canalis sinuosus* (CS). The CS is a tortuous bone channel originating from the infraorbital canal slightly posterior to the infraorbital foramen and coursing in an anterolateral direction to the anterior wall of the nasal antrum below the orbital margin [8, 25]. The CS turns medially to course below the infraorbital foramen toward the lateral wall of the nasal fossa where it curves sharply downward along the pyriform aperture to reach the anterior maxilla (Fig. 1).

The aim of the present study was to evaluate the frequency of accessory canals within the anterior maxilla other than the nasopalatine canal using limited CBCT, and to assess the size and course of these canals. Further, possible correlations of accessory canals with age and gender were analyzed.

Materials and methods

This observational study was designed as a retrospective analysis of CBCT images obtained between January and July 2011 in the Department of Oral Surgery and Stomatology, University of Bern, Switzerland. Cases were enrolled provided the scans showed the anterior area of the maxilla including the distal aspects of the canines and the full height of maxillary bone from the alveolar crest to the pyriform aperture. All patient identifiers were removed from the image files, and the retrospective study was deemed exempt from review by the ethical committee of the State of Bern. The study was performed according to the declaration of Helsinki. The initial sample consisted of 604 CBCT patient files that included the maxilla. Of these, 428 did not meet the selection criteria and were eliminated from the data set resulting a final sample comprising 176 patients.

Cone beam computed tomography scans (3D Accuitomo XYZ Slice View Tomograph; Morita, Kyoto, Japan) were taken with a basic voxel size of 0.08 mm, and exposure settings of 5.0–7.0 mA and 80 kV. The scanning time was 17.5 s. Cylindrical volumes (fields of view) measured 60 × 60 mm or 80 × 80 mm. The data were reconstructed with a slice thickness of 0.5 mm at an interval of 0.5 mm. CBCT images were viewed on a computer screen and reformatted into multiplanar reconstructions to obtain the most appropriate sections for assessment and measurements of accessory canals. The alignment and measurements of the CBCT images were performed using specialized software (i-Dixel; Morita, Kyoto, Japan).

The CBCT images were screened and evaluated for the following parameters:

X-slice (sagittal view) presence of accessory canals with distinct bone channels coursing through the entire anterior maxilla.
Y-slice (coronal view) direction of accessory canals, either communicating with the *canalis sinuosus*, or reaching the nasal floor in a vertical direction.
Z-slice (axial view) largest diameter of accessory canals (minimum 1.00 mm), location of accessory canals related to adjacent teeth.

Measurements and assessment of location and communication of accessory canals were performed twice by the same observer with an interval of at least 2 months between evaluations. The values were deemed not significantly different (see "Results" section) and the second assessment group was used for analyses.

Statistical analysis

Data were first analyzed descriptively and complemented with 95 % confidence intervals for summary measures. Between group differences were compared using the *t* test, Wilcoxon rank sum test or Chi square test where appropriate. Cohen's Kappa was used to assess intraobserver agreement for categorical data and the mean difference and the corresponding 95 % confidence interval for measuring test–retest variability for continuous data. Univariate linear regression models were used to assess any association between age and gender and diameter of the canal. All statistical analyses were performed using Stata 11.2 (StataCorp, College Station, TX, USA).

Results

Sample age ranged from 10 to 87 years with a mean of 55.4 years and a median of 58 years. Forty-nine patients (27.8 %) presented a total of 67 accessory canals in the

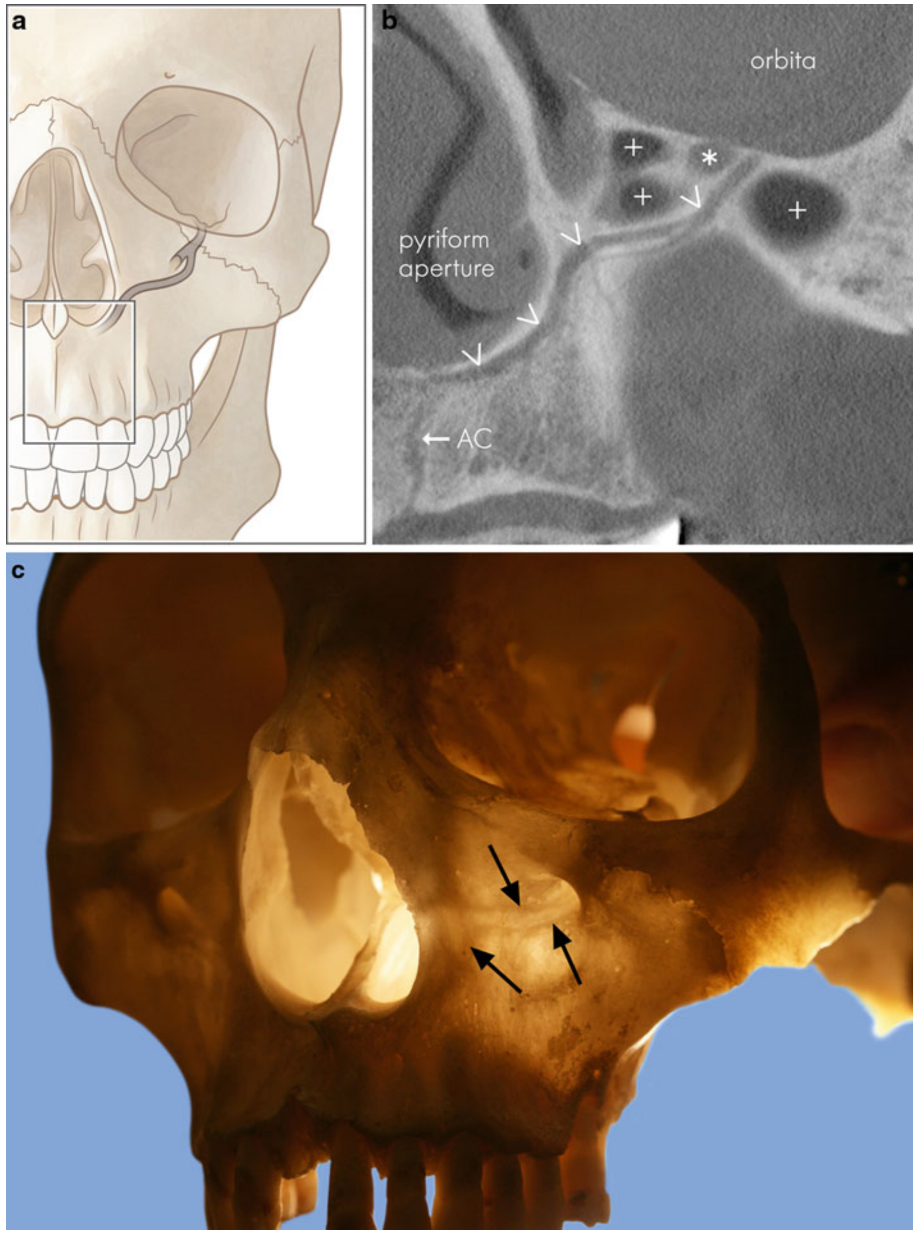

Fig. 1 **a** Schematic illustration of the *canalis sinuosus* originating from the infraorbital canal and coursing toward the pyriform aperture. Rectangle marks region of interest in the present study (see also Figs. 2a, 3a, 4a). **b** Reformatted coronal plane of a CBCT image exhibits the tortuous course of the *canalis sinuosus* (*greater than symbol*) in a 62-year-old woman (*asterisk* infraorbital canal, *plus symbol* bays of maxillary sinus, *AC* accessory canal). **c** Transilluminated skull showing *canalis sinuosus* (*arrows*) on *left side*

anterior maxilla (Table 1). The mean diameter of accessory canals was 1.31 mm (median 1.23 mm, range 1.01–2.13 mm, standard deviation $\pm$ 0.26 mm). Gender ($p =$ 0.383) and age ($p = 0.976$) did not significantly affect the diameter.

The accessory canals were located most frequently palatal to the left central incisor ($n = 20$) and palatal to the right central incisor ($n = 18$) (Table 2). Forty accessory canals (59.7 %) were found on the left side, and 27 (40.3 %) were located on the right side.

With regard to gender, males had a higher frequency of accessory canals (33.0 %) than females (22.7 %) (Table 3), but this difference was not statistically significant ($p = 0.130$). None of the patients in the youngest age group ($\leq$20 years) presented with an accessory canal. The age groups 21–40, 41–60 years, and older than 60 years, demonstrated a steady increase of occurrence of accessory canals ranging from 21.4 % (age group 21–40 years) to 32.9 % (age group > 60 years), but this difference in age distribution was not statistically significant ($p = 0.115$). Also, older individuals tended to have more than one accessory canal (Table 4), but the number of accessory canals per individual did not significantly differ across the age groups ($p = 0.165$).

Thirty-eight accessory canals (56.7 %) presented a curved communication with the CS (Fig. 2). Twenty-six canals had a straight vertical direction from the medial aspect of the pyriform aperture (Fig. 3). Three canals

Table 1 Number of accessory canals in the anterior maxilla per subject with canal diameter ≥1.00 mm

Number of accessory canals per subject	Number of subjects	Total number of accessory canals
1 Canal	35	35
2 Canals	11	22
3 Canals	2	6
4 Canals	1	4
Total	49	67

(all located palatal to central incisors) presented a Y-shape branching pattern of the accessory canals within the anterior maxilla (Fig. 4). All canals in the areas of lateral incisors and canines connected to the ipsilateral CS. In contrast, accessory canals in the area of central incisors most frequently (26 out of 38, 68.4 %) originated from the ipsilateral medial aspect of the pyriform aperture (Table 2).

With regard to comparison of the two assessments by the same observer for the location of accessory canals, the correlation was 100 % and the Cohen's kappa value 1.00 representing a very good correlation. For the direction of accessory canals the correlation was 96.27 % and the Cohen's kappa value 0.88, also representing a very good correlation. For the diameter of the accessory canals the mean difference between both measurements was 0.014 mm and it was not statistically significant ($p = 0.323$).

Discussion

The present radiographic study aimed at evaluating the presence, size, and course of accessory canals in the anterior maxilla using limited CBCT. To date, only one

Table 3 Frequency of cases with accessory canals in the anterior maxilla per gender and age groups

	Sample number (%)	Cases with accessory canals	Percentage of cases with accessory canals (%)
All	176 (100)	49	27.8
Male	88 (50)	29	33.0
Female	88 (50)	20	22.7
≤20 years	12 (6.8)	0	0
21–40 years	14 (8.0)	3	21.4
41–60 years	71 (40.3)	20	28.2
>60 years	79 (44.9)	26	32.9

study has assessed these anatomical variations in the anterior maxilla by means of CBCT [7]. A similar study evaluated the canine/premolar area using CT/CBCT [22]. Previous case reports have documented accessory canals using periapical radiography, computed tomography, and CBCT [11, 14, 19, 23]. The majority if not all of these reports have documented a bone channel within the anterior maxilla communicating with the CS. The CS is described as transmitting the anterior superior alveolar nerves (ASAN) and vessels to the anterior maxilla [25].

Heasman [8] studied the path of the ASAN and their relation to local anesthesia and surgery of the maxillary antrum in 19 hemi-sectioned human cadaver heads. The diameter of the ASAN was found consistently to be between one half and one-third that of the infraorbital nerve. The position of origin of the ASAN from the infraorbital nerve ranged from 2 to 20 mm (in two dissections a dual origin was present), and the vertical distance between the infraorbital foramen and the CS ranged from 0 to 9 mm [8]. Robinson and Wormald [17] assessed the pattern of ASAN in 40 sides of 20 human cadaver

Table 2 Location and communication (Com) of accessory canals in the anterior maxilla

Location of accessory canals	Com with right *canalis sinuosus*	Com with right aspect of pyriform aperture	Y-shape on right side	Y-shape on left side	Com with left aspect of pyriform aperture	Com with left *canalis sinuosus*	Sample number
Palatal to right canine	3						3
Palatal to right lateral incisor	6						6
Palatal to right central incisor	5	11	2				18
Palatal to left central incisor				1	15	4	20
Palatal to left lateral incisor						14	14
Palatal to left canine						6	6
Total	14	11	2	1	15	24	67

Table 4 Distribution of number of accessory canals in the anterior maxilla per individual within age groups

	1 Canal	2 Canals	3 Canals	4 Canals	Sample number
≤20 years	0	0	0	0	0
21–40 years	3 (100 %)	0	0	0	3 (100 %)
41–60 years	13 (65 %)	6 (30 %)	1 (5 %)	0	20 (100 %)
>60 years	19 (73.1 %)	5 (19.2 %)	1 (3.8 %)	1 (3.8 %)	26 (100 %)
Total	35	11	2	1	49

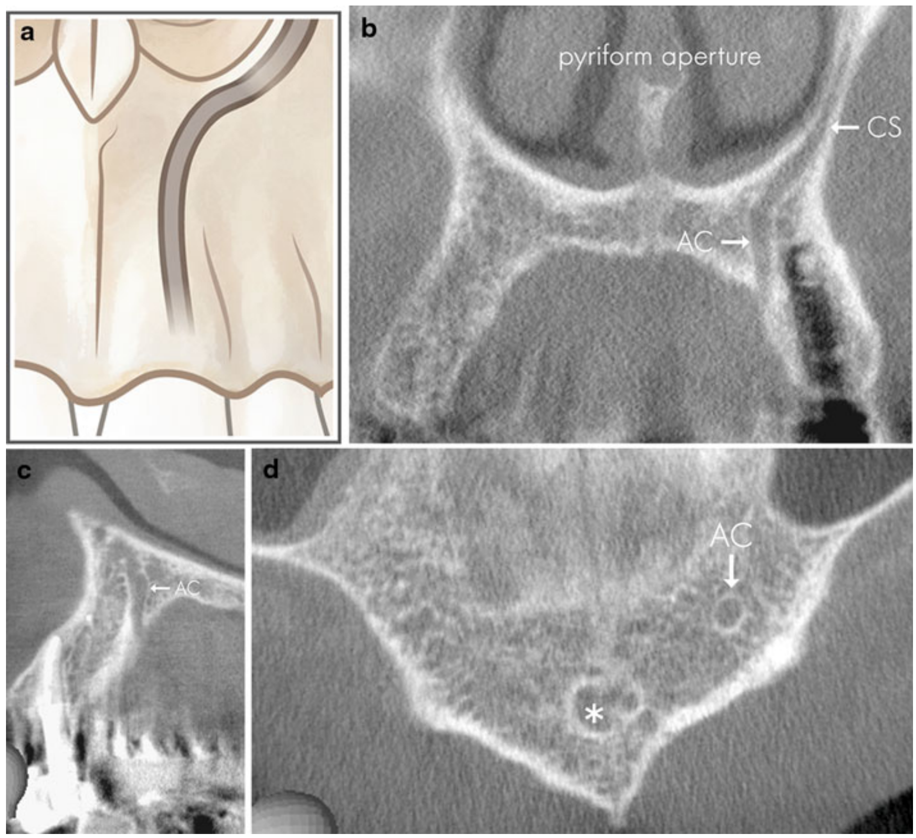

Fig. 2 **a** Schematic illustration of an accessory canal originating from the *canalis sinuosus* and coursing in a curved direction toward the alveolar process. **b** Reformatted CBCT image in coronal plane demonstrates an accessory canal (*AC*) curving downward from the *canalis sinuosus* (*CS*) into the alveolar ridge in a 54-year-old woman. **c** Reformatted CBCT image in sagittal plane exhibits the same accessory canal (*AC*) exiting at the palatal aspect of the alveolar process. **d** Reformatted CBCT image in axial plane shows the relatively large accessory canal (*AC*) with a distinct cortical lining in the region of the left canine (*asterisk* nasopalatine canal)

heads. The ASAN emerged as a single trunk in 30 sides (75 %) and in a double trunk in ten sides (25 %). Within the anterior wall, 16 sides (40 %) presented with multiple branches leaving the ASAN trunk(s), 8 sides (20 %) had a single branch, and no branching was seen in 16 sides (40 %) [17]. The authors concluded that the safest entry point for a canine fossa puncture to the maxillary sinus is the bisection of a vertical mid-pupillary line and of a horizontal line through the floor of the pyriform aperture.

Given the small diameter (<1 mm) of ASAN in the bony mass of the anterior maxilla, these structures are normally not visible on periapical or panoramic radiographs. Shelley et al. [19] presented a case of accessory canal manifested as a periapical radiolucency on an upper canine. The author interpreted the distinct radiolucent channel with corticated borders as typical of a neurovascular canal. In the case report by Kohavi [11], the author misinterpreted a wide bilateral tunnel along the pyriform aperture descending into the alveolar bone as a channel containing the posterior superior alveolar artery. However, the panoramic, axial, and cross-sectional computed tomography slices included in their paper show the typical course of the CS. Even more confusing is the report by Valcu et al. [23] in which a lateral incisive canal was considered as an aberrant form of clefting. However, the computed tomography images they reported document a large and a small bone channel within the alveolar process below the nasal fossa, communicating with the CS along the pyriform aperture. The case presented by Neves et al. [14] is a well-documented and correctly interpreted

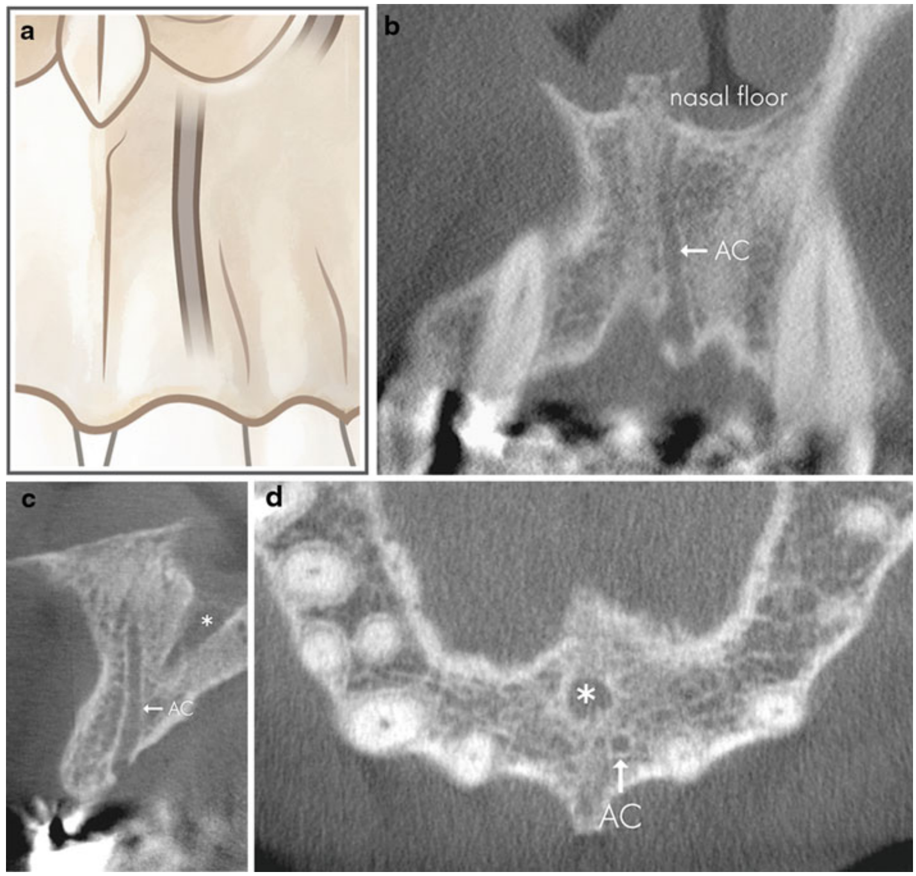

Fig. 3 **a** Schematic illustration of an accessory canal with a vertical direction from the medial aspect of the nasal floor toward the alveolar ridge. **b** Reformatted CBCT image in coronal plane demonstrates an accessory canal (*AC*) coursing from the medial aspect of the nasal floor toward the alveolar ridge in a 45-year-old woman. **c** Reformatted CBCT image in sagittal plane exhibits the same accessory canal (*AC*) exiting at the palatal aspect of the alveolar process (*asterisk* nasopalatine canal). **d** Reformatted CBCT image in axial plane shows the accessory canal (*AC*) in the region of the missing left central incisor (*asterisk* nasopalatine canal)

bilateral extension of the CS into the alveolar bone with exiting foramina palatal to the lateral incisors.

The present study with CBCT has found accessory canals in the anterior maxilla in 27.8 % of 176 patients. A similar CBCT study [7] including 178 subjects reported a frequency of 15.7 %, whereas another CT/CBCT study [22] of 65 patients described a bony canal palatal to the maxillary canines in 32.9 %. The latter study included bony canals ≥0.5 mm what might explain the higher incidence of accessory canals although only the canine area was evaluated. The present study and the study by de Oliveira-Santos et al. [7] only included accessory canals with a diameter ≥1.0 mm, hence explaining the lower frequency even though the full anterior maxilla was evaluated opposed to canine areas only in the study by Temmerman et al. [22].

The mean diameter of the accessory canals was similar in all three studies: 1.31 mm in the present study, 1.23 mm in the analysis by Temmerman et al. [22], and 1.4 mm in the study by de Oliveira-Santos et al. [7]. However, the latter study measured the diameter of the (oblique) palatal opening of accessory canals rather than the diameter of the canal, what might explain the size difference. Whether the size and occurrence of accessory canals in the anterior maxilla correlates with the size of skull or teeth has not been studied yet.

With regard to the distribution of accessory canals within the anterior maxilla, there was predilection of canal location palatal to the central incisors (56.7 %) in the present study. It is not possible to compare this value with the other studies due to differences in the ROI, since either only the canine area was evaluated [22], or the ROI also included the first premolar region [7]. It was further found difficult to differentiate a location close to the nasopalatine canal versus palatal to a central incisor—hence, this study pooled cases with accessory canals close to the nasopalatine canal into the category “palatal to central incisor”.

Regarding the course of the accessory canals in the present study, 56.7 % of canals communicated with the ipsilateral maxillary extension of the *canalis sinuosus*. In the study by Temmermann et al. [22] limited to the canine area, it was reported that the canal always started at the palatal aspect of the canine to run in a latero-cranial direction. In the study by de Oliveira-Santos et al. [7], in 41.2 % a direct extension of accessory canals to the *canalis sinuosus* was described, but 52.9 % of canals were found to have an upward or oblique direction toward the anterior portion of the floor of the nasal cavity. This finding was less frequently seen in this study (in 38.8 %).

Slightly more accessory canals were found in males (33.0 %) compared to females (22.7 %) in the present

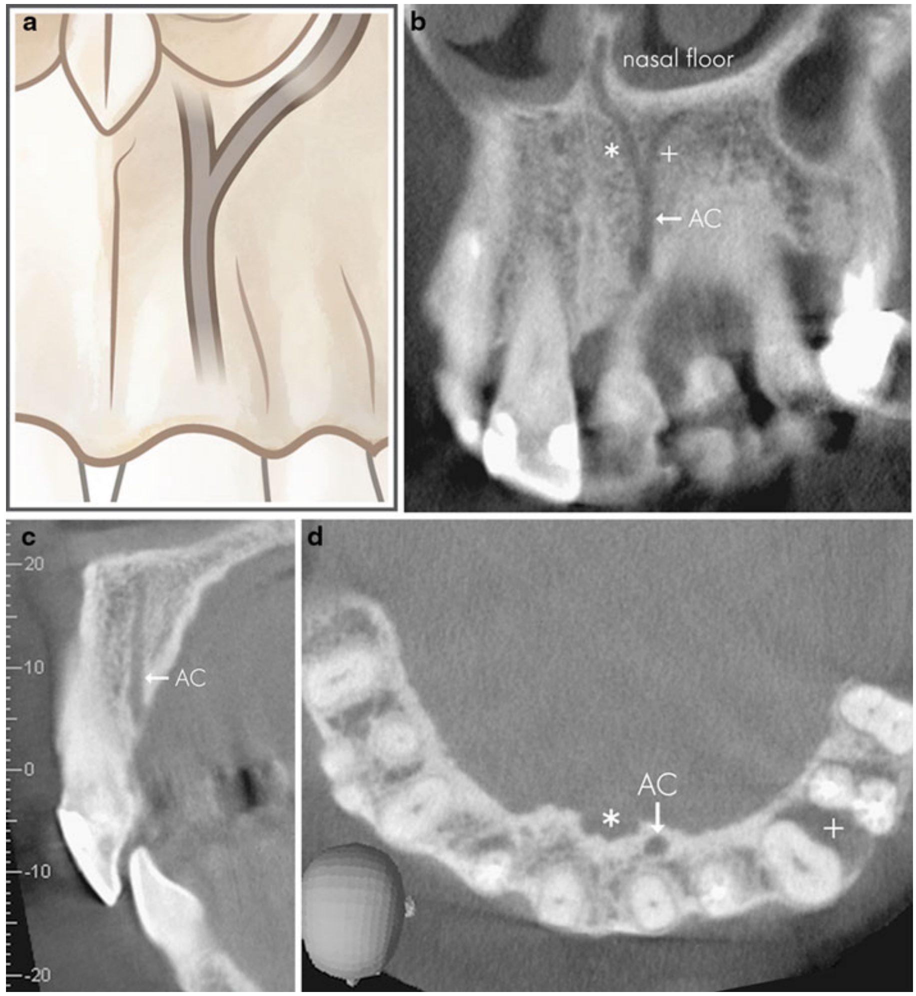

Fig. 4 **a** Schematic illustration of an accessory canal with a Y-shape configuration with one branch originating from the *canalis sinuosus* and the other branch coming from the medial aspect of the nasal floor. **b** Reformatted CBCT image in coronal plane demonstrates an accessory canal (*AC*) with a Y-shape configuration in a 55-year-old man with one branch (*plus symbol*) originating from the *canalis sinuosus* and the other (*asterisk*) from the medial aspect of the nasal floor. **c** Reformatted CBCT image in sagittal plane exhibits the same accessory canal (*AC*) exiting at the palatal aspect of the left central incisor. **d** Reformatted CBCT image in axial plane shows the distinct accessory canal (*AC*) within the palatal cortex of the left central incisor (*asterisk* incisive foramen), and a bone lesion (*plus symbol*) is visible between the left canine and left first premolar and at the distal aspect of that premolar

study. There was also a tendency of seeing more accessory canals in older than in younger subjects in the present study, but the presence of accessory canals was neither correlated with age nor gender. No statistically significant difference regarding the frequency of accessory canals and the gender or age was similarly reported by de Oliveira-Santos et al. [7].

In conclusion, the present study confirmed previous reports about the detection of bone channels other than the nasopalatine canal within the anterior maxilla by using limited CBCT. More than half of the examined subjects of this study presented with at least one accessory canal (55.1 %), but defining a minimum diameter of 1 mm, 27.8 % of cases presented one or multiple accessory canals in the anterior maxilla other than the nasopalatine canal. 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. Currently, studies on accessory canals in the anterior maxilla correlating radiographic findings with gross anatomy dissection are lacking. Further, no evidence is available concerning the effects and clinical significance of surgical damage to the *canalis sinuosus* or to the accessory canals in the anterior maxilla. Future work will be directed at correlating the occurrence of anterior accessory canals radiographically with gross anatomical dissections.

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Conflict of interest The authors declare that they do not have any conflict of interest.

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