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ORIGINAL ARTICLE

Cone beam computed tomographic analysis of neurovascular anatomical variations other than the nasopalatine canal in the anterior maxilla in a pediatric population

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Abstract

Purpose This study aimed to analyze and assess the presence of accessory foramina and canals other than the nasopalatine canal (NPC) in the anterior palate region in a pediatric population, through cone beam computed tomography (CBCT) images, describing their location, direction, and diameter.

Study design Reformatted sagittal, coronal and axial slices of 368 individual CBCT images were analyzed. 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 Eighty-two patients (22.3 %); presented additional foramina in the anterior palate (AFP) and in total 131 additional foramina were registered. A higher frequency of accessory canals was observed in girls (29.5 %) than in boys (15.7 %) ($p = 0.012$). The average diameter of AFP was 1.2 mm. Their location was variable, with most of the cases occurring in the alveolar process near the incisors or canines. Gender and age did not significantly influence the diameter.

Conclusions The study confirms the presence of bone channels within the anterior maxilla other than the NPC in a pediatric population. Over 22 % of the population studied had additional foramina other than the NPC in the anterior palate, between 1 and 1.7 mm wide, with variable locations.

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Introduction

The most prominent anatomical structure within the anterior maxilla is the nasopalatine canal (NPC) [1, 15]. 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 [18]. Knowledge on the development of the nasopalatine region and NPC in humans is necessary for understanding the morphology of this region and the establishment of theories that may clarify the etiopathogenesis of lesions that occur in this anatomic region [3]. Both pathological symptoms and morphological variation or change of the NPC may remain a complex restorative challenge. Indeed, before carrying out a surgical procedure in the anterior maxilla, it is of utmost importance to consider and precisely locate the presence of neurovascular bundles [8]. Jacobs et al. [5] first reported that the use of high-resolution magnetic resonance imaging for micro-anatomical observations of jaw bone neurovascularization can provide new insights and give clear answers to the ongoing debates.

Current articles have drawn attention to radiographically visible accessory canals that may carry neurovascular structures to the anterior maxilla. Various terms have been applied to these canals including lateral incisive canal, neurovascular variations in the anterior palate, or accessory canals [11].

Cone beam computed tomography (CBCT) which has raised the interest in revisiting the anatomical features of the jaws, particularly regarding neurovascularization and possible anatomical variations [14, 16] allow a precise three-dimensional evaluation of the bone quality and quantity of the maxilla. Injuries of major vascular and nerve branches should be avoided to achieve safer surgical procedures and better outcomes, which require careful preoperative observation [7].

The purpose of this study was to determine the pediatric anatomic variability of the accessory canals within the anterior maxilla other than the NPC using CBCT, and to assess the characteristics of these canals.

Materials and methods

The materials for this study were obtained from the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Erciyes University. 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. The exclusion criteria were described as follows: inadequate CBCT image quality (patient movement, operator errors, etc.); any pathologic lesions and unerupted teeth in the related region and presence of bony lesions altering the course of neurovascular structures.

Evaluation of the images

All the CBCT images were evaluated by the same oral radiologist (AES with 5 years of experience). The CBCT mandibular images were analyzed in the NNT viewer which is a simple version of the NNT software of the CBCT (Newtom 5G, QR, Verona, Italy) machine in a Dell Precision T5400 workstation (Dell, Round Rock, TX, USA), and a 32-in. Dell LCD screen with a resolution of 1,280 × 1,024 pixels in a darkroom. The contrast and brightness of the images were adjusted using the image processing tool in the software to ensure optimal visualization.

The following parameters were screened and evaluated: gender (boys; girls); presence of additional foramina in the anterior palate (AFP) at least 1 mm in diameter; location of AFP (central incisors region; between central and lateral incisors; lateral incisor region; canine region; first premolar region, and adjacent to incisive foramen: posterior, anterior, or lateral); diameter of AFP (in mm); and direction of bony canals associated with AFP. Diameters were determined by measuring the palatine opening of the additional canal on both coronal and cross-sectional images.

The CBCT images were screened and evaluated for the following parameters

Sagittal view Presence of accessory canals with distinct bone channels coursing through the entire anterior maxilla.

Table 1 Distribution of number of accessory canals other than the nasopalatine canal in the anterior maxilla per individual within age groups

Age group	I Canal	II Canal	III Canal	IV Canal	Sample number (%)
<9 years	3	1	0	0	4 (4.9)
9–12 years	17	4	7	1	29 (35.4)
>12 years	31	11	5	2	49 (59.8)
Total	51	16	12	3	82 (100)

Coronal view Direction of accessory canals, either communicating with the *canalis sinuosus*, or reaching the nasal floor in a vertical direction.

Axial view Largest diameter of accessory canals (minimum 1.00 mm), location of accessory canals related to adjacent teeth.

Finally, 1 month later, 20 % of the measurements assessment of location and communication of accessory canals of the 368 cases were repeated to check intra-observer variability (Kappa coefficient for categorical data).

Statistical analysis

The values obtained were tabulated; and the mean average and respective standard deviations (SDs) were calculated for all distances studied. The data analyses were performed by using the Statistical Package for the Social Sciences (SPSS), version 16.0 (SPSS Inc., Chicago, IL). Categorical variables were shown by *n* and % values and compared using Pearson's chi-square test and statistical significance was determined at the level of $p < 0.05$.

Results

The study subjects consisted of 176 (47 %) girls and 192 (53 %) boys. The mean age of the patients was 11.23 (SD 2.37), with ages ranging from 6 to 15 years. The age groups <9 years, 9–12 years, and older than 12 years, demonstrated a steady increase of occurrence of accessory canals ranging from 4.9 % (age group <9 years) to 59.8 % (age group >12 years) (Table 1).

Eighty-two patients (22.3 %; 52 girls, 30 boys) presented a total of 131 accessory canals in the anterior maxilla (Tables 2, 3). Statistically significant differences between patients with or without AFP were found for gender ($p = 0.012$).The average diameter of AFP was 1.12 mm (range 1–1.7 mm, SD ±0.26 mm). In eight cases, additional foramina (bilaterally) were observed.

The accessory canals were located most frequently palatal to the left lateral incisor ($n = 16$) and palatal to the right lateral incisor ($n = 15$). Sixty-five accessory canals (49.6 %)

were found on the right side, 60 (45.8 %) were located on the left side and six cases were located posteriorly from the incisive foramen. Their location was variable, with most of the cases occurring in the alveolar process near the incisors or canines (Fig 1a–e). These AFP were associated with bony canals that, in some cases, had an upward or oblique direction toward the anterior portion of the nasal cavity floor ($n = 9$). In other cases ($n = 6$), the bony canal presented as a direct extension of the canalis sinuosus (CS), in an upward direction laterally to the nasal cavity aperture. In two cases, the bony canal associated with AFP located adjacent to the incisive canal (one case posteriorly and one case laterally to the incisive foramen) joined the NPC superiorly (Fig. 2a–d).

Table 2 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
	Boys	Girls	
1 Canal	18	33	51
2 Canals	6	10	32
3 Canals	6	6	36
4 Canals	0	3	12
Total	30	52	131

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

	Sample number (%)	Cases with accessory canals	Percentage of cases with accessory canals (%)
All	368 (100)	82	22.3
Girls	176 (47.8)	52	29.5
Boys	192 (52.2)	30	15.7

P 0.012

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 97.13 % and the Cohen's kappa value 0.92, also representing a very good correlation. For the diameter of the accessory canals the mean difference between both measurements was 0.012 mm and it was not statistically significant ($p = 0.471$).

Discussion

Anatomical variations in the premaxillar region (PMR) are infrequently described in the literature and, in most reports,

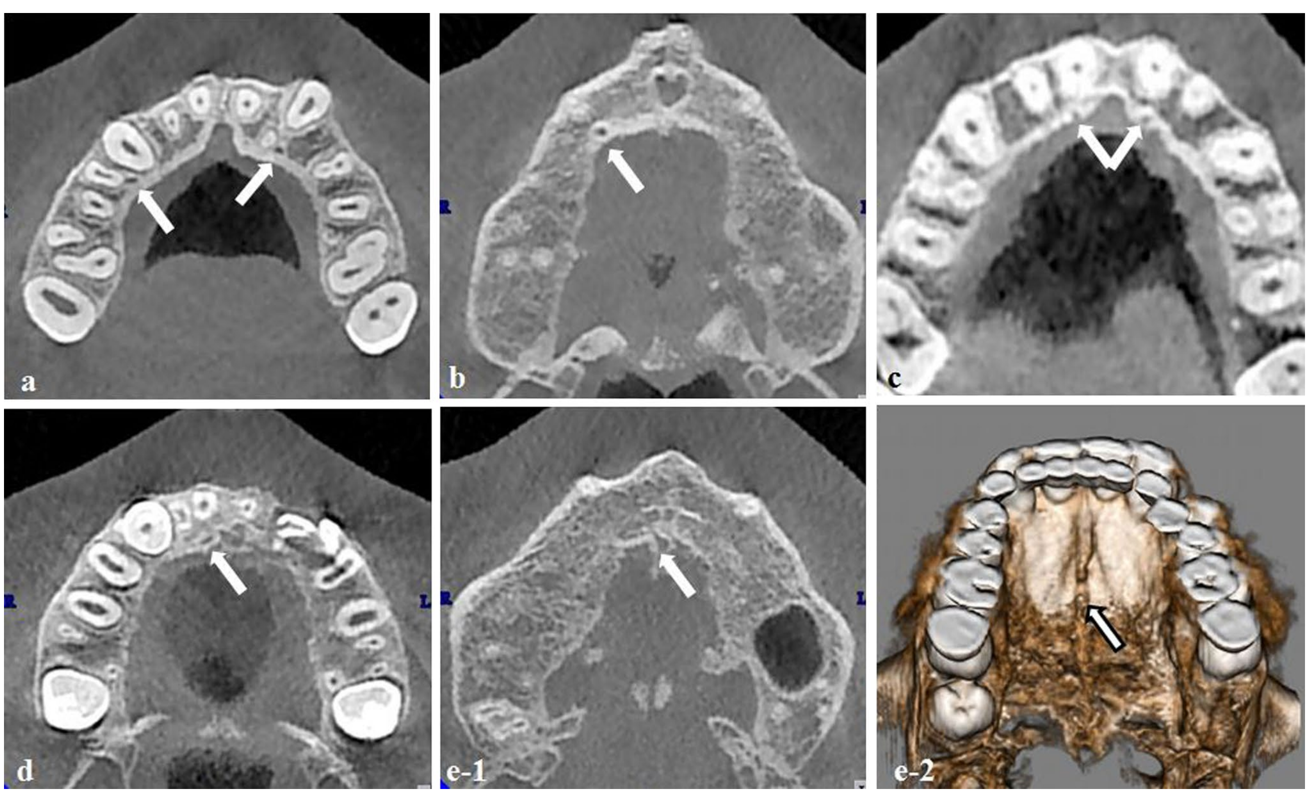

Fig. 1 Reformatted CBCT image in axial plane shows the accessory canals (*arrows*) within the palatal cortex (**a**–**d**). The accessory canal located adjacent to the incisive foramen joined the nasopalatine canal superiorly (**e-1** and **e-2**)

Fig. 2 Coronal (**a** and **b**) views of a CBCT scan showing additional foramen (*arrows*) and canal presenting as a direct extension of canalis sinuosus (*asterisk*). Sagittal and coronal (**c-1** and **c-2**) view of a CBCT scan of same child showing an additional foramen (*arrow*) located posteriorly from the incisive foramen and connected superiorly to the nasopalatine canal. Reformatted CBCT image in sagittal plane (**d-1**) and 3-D view exhibit accessory canal exiting at the palatal aspect of the right canine

are related to the NPC [10]. The presence of accessory canals and foramina in the PMR is often omitted in clinical practice. These variations can only be detected preoperatively on advanced imaging, and their presence can have a straight effect on therapeutic success [11].

The anterior superior alveolar nerve (ASAN) originates from the infraorbital nerve and is the major nerve of the superior alveolar nerves. It gives off neurovascular branches to form a dental plexus in the alveolar process, supplying the canines and incisors. Given the small diameter (<1 mm) of anterior superior alveolar nerves (ASAN) in the bony mass of the anterior maxilla, these structures are normally not visible on conventional images [21]. In present study, we exhibit that additional palatine foramina at least 1 mm in diameter may be found in around 22.3 % of patients of both genders. Such foramina and bony canals may be clinically relevant because they may enclose neurovascular content of significant caliber.

The ASAN and artery also reach the anterior maxilla through a bony canal named canalis sinuosus (CS). CS is a normal anatomical feature that corresponds to a poorly recognized neurovascular canal [9] to supply the soft tissues, as well as adjacent incisors and canines [14]. The infraorbital canal issues a small branch called the CS on its lateral face close to its midpoint to allow passage of the anterior superior alveolar nerve. CS has not been properly described, and requires special attention in surgical procedures in that region.

Plain radiographs have limited value in showing some intrabony courses of neurovascular structures [19]; therefore, CBCT images may have an important role in the preoperative evaluation of anatomic structures by allowing detailed tridimensional assessments. In the case report by Kohavi [6], the authors reported that relatively wide canals were registered bilaterally on computerized tomography (CT) images, with palatine openings in the canine/premolar region. On multi-slice CT images, Temmerman et al. [19] observed that in one-third of cases additional bony canals in the upper canine region started palatally and coursed in a latero-cranial direction. Shelley et al. [17] assessed a case of accessory canal manifested as a periapical radiolucency on an upper canine and interpreted the distinct radiolucent channel with corticated borders as typical of a neurovascular canal. The case presented by Neves et al. [11] is a well-documented and correctly interpreted bilateral extension of the CS into the alveolar bone with exiting foramina palatal to the lateral incisors. The case reported by Valcu et al. [20] in which a lateral incisive canal was considered as an aberrant form of clefting. In the present study, prevalence of additional canals was much lower (nearly 16 %) and included other locations than just canines and incisors region. This difference in prevalence is probably because those authors took into account even minute canals with 0.5 mm in diameter. In present study, the authors demonstrate two cases of AFP in the vicinity of the incisive foramen that were connected superiorly to the incisive canal, representing an anatomical variation in this neurovascular structure.

Heasman [4] studied 19 hemi-sectioned human cadaver heads and 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 [4]. Robinson and Wormald [13] presented the pattern of ASAN in 40 sides of 20 human cadaver 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 %) [13].

This study with CBCT has found accessory canals in the anterior maxilla in 22.3 % of 368 pediatric populations. A similar CBCT study [2] including 178 subjects reported a frequency of 15.7 %, whereas another CT/CBCT study [14] of 65 patients described a bony canal palatal to the maxillary canines in 32.9 %. The latter study included bony canals 0.5 mm which might explain the higher incidence of accessory canals although only the canine area was evaluated. This study and the studies by de Oliveira-Santos et al. [2] and von Arx [21] only included accessory canals with a diameter 1.0 mm, hence explaining the lower frequency even though the full anterior maxilla was evaluated as opposed to canine areas only in the study by Temmerman et al. [19].

The mean diameter of the accessory canals was similar in all three studies: 1.23 mm in the analysis by Temmerman et al. [19], 1.31 mm in the von Arx et al. study [21], and 1.4 mm in the study by de Oliveira-Santos et al. [2]. In present report, this ratio is 1.12 mm. However, the latter study measured the diameter of the (oblique) palatal opening of accessory canals rather than the diameter of the canal, which might explain the size difference.

In the present study, accessory canals were found in girls (29.5 %) more than in boys (15.7 %). In the von Arx et al. study [21], slightly more accessory canals were found in males (33.0 %) compared to females (22.7 %) There was also a tendency of seeing more accessory canals in older than in younger subjects in their 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. [2].

In conclusion, the present study provides new information to the literature concerning the identification of the presence of bone channels within the anterior maxilla other than the NPC in a pediatric population. In this study, we demonstrate that additional palatine foramina at least 1 mm in diameter may be found in around 22 % of patients of both genders and different age groups. Their location was variable, with most of the cases occurring in the alveolar process near the incisors or canines.

Conflict of interest The authors state that there are no conflicts of interest.

References

1. Bornstein MM, Balsiger R, Sendi P, von Arx T (2011) Morphology of the nasopalatine canal and dental implant surgery: a radiographic analysis of 100 consecutive patients using limited cone-beam computed tomography. Clin Oral Implants Res 22:295–301
2. de Oliveira-Santos C, Rubira-Bullen IRF, Monteiro SA, Leo'n JE, Jacobs R (2013) Neurovascular anatomical variations in the anterior palate observed on CBCT images. Clin Oral Impl Res 24(9):1044–1048
3. Falci SG, Verli FD, Consolaro A, Santos CR (2013) Morphological characterization of the nasopalatine region in human fetuses and its association to pathologies. J Appl Oral Sci 21:250–255
4. Heasman PA (1984) Clinical anatomy of the superior alveolar nerves. Br J Oral Maxillofac Surg 22:439–447
5. Jacobs R, Lambrichts I, Liang X et al (2007) Neurovascularization of the anterior jaw bones revisited using high-resolution magnetic resonance imaging. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 103:683–693
6. Kohavi D (1994) Demonstration of unusually wide artery in the maxillary alveolar bone using a reformatting program of computed tomography: a case report. Int J Oral Maxillofac Implants 9:444–448
7. Liang X, Jacobs R, Lambrichts I (2006) Appearance, location, course and morphology of the superior and inferior genial spinal foramina and their bony canals: an assessment on spiral CT scan. Surg Radiol Anat 28:98–104
8. Liang X, Jacobs R, Martens W, Hu Y et al (2009) Macro- and micro-anatomical, histological and computed tomography scan characterization of the nasopalatine canal. J Clin Periodontol 36:598–603
9. Liang X, Lambrichts I, Corpas L et al (2008) Neurovascular disturbance associated with implant placement in the anterior mandible and its surgical implications: literature review including report of a case. Chin J Dent Res 11:56–64
10. Mraiwa N, Jacobs R, Van Cleynenbreugel J et al (2004) The nasopalatine canal revisited using 2D and 3D CT imaging. Dentomaxillofac Radiol 33:396–402
11. Neves FS, Crusoe-Souza M, Franco LC et al (2012) Canalis sinuosus: a rare anatomical variation. Surg Radiol Anat 34:563–566
12. Oliveira-Santos C, Souza PHC, Berti-Couto SA et al (2012) Assessment of variations of the mandibular canal through cone beam computed tomography. Clin Oral Investig 16:387–393

13. Robinson S, Wormald PJ (2005) Patterns of innervation of the anterior maxilla: a cadaver study with relevance to canine fossa puncture of the maxillary sinus. Laryngoscope 115:1785–1788
14. Rodella LF, Buffoli B, Labanca M, Rezzani R (2012) A review of the mandibular and maxillary nerve supplies and their clinical relevance. Arch Oral Biol 57:323–334
15. Sekerci AE, Buyuk SK, Cantekin K (2014) Cone-beam computed tomographic analysis of the morphological characterization of the nasopalatine canal in a pediatric population. Surg Radiol Anat. doi:10.1007/s00276-014-1271-0
16. Sekerci AE, Cantekin K, Aydinbelge M (2013) Cone beam computed tomographic analysis of the shape, height, and location of the mandibular lingula in a population of children. Biomed Res Int. doi:10.1155/2013/825453
17. Shelley AM, Rushton VE, Horner K (1999) Canalis sinuosus mimicking a periapical inflammatory lesion. Br Dent J 186:378–379
18. Song WC, Jo DI, Lee JY et al (2009) Microanatomy of the incisive canal using three-dimensional reconstruction of microCT images: an ex vivo study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 108:583–590
19. Temmerman A, Hertele' S, Teughels W et al (2011) Are panoramic images reliable in planning sinus augmentation procedures? Clin Oral Implants Res 22(2):189–194
20. Valcu M, Rusu MC, Sendroiu VM, Didilescu AC (2011) The lateral incisive canals of the adult hard palate–aberrant anatomy of a minor form of clefting? Rom J Morphol Embryol 52:947–949
21. von Arx T, Lozanoff S, Sendi P, Bornstein MM (2013) Assessment of bone channels other than the nasopalatine canal in the anterior maxilla using limited cone beam computed tomography. Surg Radiol Anat 35:783–790