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ORIGINAL ARTICLE

Tomographic evaluation of incisive canal, canalis sinuosus and posterior superior alveolar canal

ARTIGO ORIGINAL

Avaliação tomográfica do canal incisivo, canal sinuoso e canal alveolar superior posterior

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Keywords: Canalis sinuosus; Incisive Canal; Maxillary Sinus; Cone-Beam Computed Tomography; Anatomical Variation.

Abstract

The identification of the incisive canal, canalis sinuosus, and posterior superior alveolar canal minimizes the occurrence of surgical complications associated with neurovascular injuries. The aim of this study was to assess the prevalence of anatomical variations in the anterior and posterior maxillary regions using cone-beam computed tomography (CBCT). A total of 291 CBCT scans were evaluated for the presence and description of anatomical variations of the incisive canal (IC), alveolar extension of the canalis sinuosus (CS), and posterior superior alveolar canal (PSA). Regarding the IC, 74.23% of CBCT scans exhibited a single-channel pattern and normal diameter. Alveolar extension of the CS was detected in 17.15% of cases and was more frequent on the right side. The variation pattern of the PSA canal was detected in 15.46% of cases, with higher prevalence on the left side in females and on the right side in males. The molar region was the most common location of this extension bilaterally. Cone-beam computed tomography is a reliable and effective strategy for evaluating anatomical variations in the maxilla, including neurovascular structures such as the incisive canal, alveolar extension of the canalis sinuosus, and posterior superior alveolar canal.

Palavras-chave: Partially edentulous jaw; Partial denture; Digital Technology.

Resumo

A identificação do canal incisivo, canalis sinuosus e canal alveolar superior posterior minimiza a ocorrência de complicações cirúrgicas associadas a lesões neurovasculares. O objetivo deste estudo foi avaliar a prevalência de variações anatômicas na região maxilar anterior e posterior por meio da tomografia computadorizada de feixe cônico (TCFC). 291 exames de TCFC foram avaliados quanto à presença e descrição da variação anatômica do canal incisivo (CI), extensão alveolar do canalis sinuosus (CS) e canal alveolar superior posterior (PSA). Em relação ao CI, 74,23% dos exames de TCFC apresentaram padrão anatômico com canal único e diâmetro normal. A extensão do CS para alveolar foi detectada em 17,15% dos casos e foi mais frequente apenas no lado direito. O padrão de variação do canal PSA foi detectado em 15,46% dos casos e foi mais frequente apenas no lado esquerdo do grupo feminino e apenas no lado direito do grupo masculino. A região molar foi a localização mais comum dessa extensão, tanto no lado direito quanto no esquerdo. A tomografia computadorizada de feixe cônico pode ser considerada uma estratégia confiável e eficaz para avaliar variações anatômicas na maxila, incluindo a detecção de variações neurovasculares, como canal incisivo, extensão alveolar do canal sinuoso e canal alveolar póstero-superior.

Introducion

Surgical interventions in the maxilla have increased concomitantly with postoperative complaints. Most complications are related to accidental injury to neurovascular structures during surgical procedures[1,2]. In the maxilla, the incisive canal (IC), alveolar extension of the canalis sinuosus (CS), and posterior superior alveolar canal (PSA) are clinically relevant due to their intraosseous paths in the alveolar ridge. The incisive canal, located in the anterior maxilla, has a "Y" shape and connects the floor of the nasal cavity to the palatal region posterior to the upper central incisors via the incisive foramen[3-5]. The canalis sinuosus, also in the anterior maxilla, originates from the infraorbital canal, follows a tortuous path near the nasal cavity, and may branch into the alveolar ridge[6,7]. In the posterior region, the PSA canal may present an intraosseous path in the alveolar ridge, increasing its clinical relevance for dental procedures[8,9].

Preoperative detection of these structures is essential. Intraoral and extraoral radiographs may be insufficient due to structural superimposition inherent in two-dimensional techniques. Volumetric imaging, such as cone-beam computed tomography (CBCT), is recommended to minimize complications associated with image overlap[10,11].

Implant-based rehabilitation planning typically includes CBCT to evaluate alveolar ridge characteristics (e.g., bone volume and density). However, identifying anatomical variations and lesions during preoperative assessment is critical[11]. CBCT enables detailed evaluation of these structures, reducing complications such as numbness, hypoesthesia, hyperesthesia, paresthesia, pain, neuroma development, and hemorrhage. Hemorrhage, frequently reported, can prolong intraoperative time and exacerbate pain and inflammation, potentially leading to orofacial neuropathic pain or permanent neural damage[12–14].

The aim of this study was to assess the prevalence of incisor canal, canalis sinuosus and posterior superior alveolar canal as well as evaluate the putative variations in these anatomic structures using cone beam computed tomography (CBCT).

Matherial and methods

Inclusion criteria:

This retrospective study, approved by the Research Ethics Committee of the State University of Ponta Grossa (protocol 42040814.2.0000.0105), followed the Declaration of Helsinki and was conducted from January to December 2014. Sample size was determined using G*Power 3.1.9.7, which recommended 141 participants per group (real power: 0.8015397 to detect the evaluated effect).

Initially, 300 CBCT scans were obtained from the archive of ILAPEO College (Curitiba, Brazil). Only full maxillary scans were included. Patient ages ranged from 5 to 93 years. Exclusion criteria involved artifacts or metallic elements in the maxilla (n= 9).

Image acquisition and evaluation:

Images were acquired using CBCT (Galileos, Sirona Dental, Germany) with a 15 cm FOV, 0.3 mm voxel size, and exposure parameters (85 kVp, 7 mA, 14 s). Reconstructions were generated using Galaxis software (Sirona Dental). Axial, coronal, sagittal, panoramic, and cross-sectional reconstructions were evaluated by a calibrated radiologist.

Anatomical variations:

1. Incisive canal:

Foraminal diameter was measured from cross-sectional sections and classified as narrowed (≤1 mm), normal (1–6 mm), or widened (>6 mm)[14,15]. Septations were classified as single-channel, two-channel, or three-channel[14] (Table 1).

Table 1. Distribution of IC regarding to age, gender, septations, and diameter

Female patients (n=176)						Male patients (n=115)					
SC	2C	3C	NoD	WD	NaD	SC	2C	3C	NoD	WD	NaD

SC: Single-channel, 2C: 2-channel, 3C: 3-channel.
NoD: Normal diameter, WD: Widened diameter, NaD: Narrowed diameter

2. Canalis sinuosus:
Presence/absence, palatal emergence, and continuity with the sinuous canal were assessed (Table2).

Table 2. Distribution of CS and PSA regarding to age, gender, and localization.

CS						PSA					
Female patients (n=176)			Male patients (n=115)			Female patients (n=176)			Male patients (n=115)		
Right side	Left side	Both sides	Right side	Left side	Both sides	Right side	Left side	Both sides	Right side	Left side	Both sides

3. Posterior superior alveolar canal (PSA):
Presence/absence, location (unilateral/bilateral), and alveolar ridge extension were recorded (Table 3).

Table 3. Distribution of presence of dental and maxillary sinus alterations

Lesions		Dental alterations		Maxillary sinus alterations	
Description	**N (%)**	**Description**	**N (%)**	**Description**	**N (%)**
Hyperdense	n=3 (1,03%)	Dental supernumerary	n=7 (2,41%)	Obliterated	n=9 (3,10%)
Extensive osteolytic	n=1 (0,34%)	Microdontia	n=1 (0,34%)	Oroantral communication	n=5 (1,72%)
Periapicopathies and periodontopathies	n=28 (9,65%)	Impactation	n=4 (1,36%)	Atrophy or hypoplasia	n=2 (0,68%)
				Alveolar Extension	n=2 (0,68%)
				Widened nutrient channels	n=2 (0,68%)
Total	n=32 (30,02%)	Total	n=12 (4,08%)	Total	n=20 (6,80%)

Other findings and conditions:
Evaluated conditions included:
- Grafting sites;
- Periapical and periodontal pathologies;
-Maxillary sinus alterations (obliteration, oroantral communication, atrophy/hypoplasia, widened nutrient canals);
- Lesions (hyperdense, extensive osteolytic);
- Dental organ alterations;
- Nasal cavity extension.

Statistical analysis:
Data were analyzed using descriptive statistics. Relationships between anatomical variations, age groups, and gender were expressed as percentages. All analyses were performed by one examiner (OSJ; kappa = 0.868).

Results

The sample comprised 291 CBCT scans. Mean age was 55.21 ± 14.24 years (range: 5–93 years), with 60.48% females (n = 176) and 39.52% males (n = 115).

Incisive canal:
In females, widened, narrowed, and normal diameter patterns occurred in 17.61% (n = 31), 5.68% (n = 10), and 76.70% (n = 135) of cases, respectively. In males, these patterns occurred in 18.26% (n = 21), 3.48% (n = 4), and 78.26% (n = 90) of cases. The single-channel pattern predominated in females (96.02%, n = 169), followed by two-channel (2.84%, n = 5) and three-channel (1.14%, n = 2). In males, single-channel prevalence was 95.65% (n = 110), followed by two-channel (3.48%, n = 4) and three-channel (0.87%, n = 1) (Table 1).

Canalis Sinuosus:
Alveolar extension of the CS was detected in 11.93% of females (n = 21/176), with right-side, left-side, and bilateral prevalence of 38.10% (n = 8), 33.33%

(n = 7), and 28.57% (n = 6), respectively. In males, prevalence was 5.22% (n = 6/115), with 66.67% (n = 4) right-side and 33.33% (n = 2) left-side involvement. The most frequent emergence site was palatal to the lateral incisor (Table 2).

Posterior superior alveolar canal:

The PSA canal was detected in 16.48% (n=29) of female patients (n=176). Considering these 29 cases, the PSA pattern was observed only on the right side in 11 cases (37.93%), only on the left side in 17 cases (58,62%), and on both sides in 1 case (3,45%). Considering both sides, molar region was the most common location of this extension (Table 2).

The male group comprised a total of 115 patients, with the PSA canal pattern detected in 16 cases (13.91%). Of the 16 cases, the PSA pattern was 47 observed only on the right side in 7 cases (43.75%), only on the left side in 4 cases (25.00%), and on both sides in 5 cases (31.25%). The most common location of the extension, both on the right and left sides, was in the molar region and the predilect side was the right one (Table 2).

Other findings and conditions:

Overall, 43.10% (n = 125) exhibited at least one condition. Bone grafts occurred in 7.24% (n = 21), and nasal cavity extension into the maxillary sinus in 0.34% (n = 1). Lesions, dental alterations, and maxillary sinus alterations are detailed in Table 3.

Discussion

Three-dimensional imaging through CBCT is a relevant differential for the diagnosis and treatment of dental disorders[16,17]. These images are especially important when surgical procedures are required, since several studies have revealed that CBCT is an effective technique for evaluating neurovascular structures[18]. In fact, the identification of these structures minimizes the occurrence of complications associated with neurovascular injuries. Therefore, the aim of this study was to evaluate the applicability of CBCT to identify incisive canal, canalis sinuosus and posterior superior alveolar canal.

Regarding to incisive canal, our results demonstrated that single channel pattern (95.65% and 96.02% in males and females, respectively) was the most prevalent, followed by 2 and 3-channel pattern. Previous studies reported that the most common morphology of the IC was of the single channel type, with 52.45% and 63.3% respectively[3,17]. Probably these differences are associated with methodological differences between the evaluated studies. In fact, the methodology used in this study did not evaluate nasal openings, since the study emphasized the anatomy of alveolar reword and its clinical implications[3,17]. These differences may be related to differences in the experimental design of each study. In fact, the methodology used in our evaluations did not evaluate nasal opening, since our objectives emphasized the alveolar ridge region and its clinical implications.

Moreover, our results also demonstrated higher prevalence of IC with normal pattern regarding to size. However, an increased diameter of this canal was detected in older patients (50-69 years old). In accordance, Soumya and collaborators (2019)[19] reported that the diameter of the incisor foramen and the length of the IC increased in older patients. Moreover, the increase is more frequent after tooth loss and aging[8,14].

The presence of alveolar extension of canalis sinuosus was detected in 11.93% and 5.22% of cases in females and males, respectively. In a retrospective study of 1.007 chinese patients, there was a prevalence of 36.9% of the accessory CS channel, 35% and 39.4% in female and male, respectively[20]. In addition, other authors have been demonstrated the highest prevalence of CS alveolar extension in females[21]. However, the higher prevalence of the CS accessory channel in males have been reported[22,23]. In fact, these differences may be related to the size of sample.

Our results demonstrated that the most common emergency site of CS channel was in the palatal region of lateral incisors, as described by Anatoly and collaborators[21]. In this context, it is important to consider that CS is not an anatomical variation, but a structure that can extend to the alveolar region[24].

In the posterior region of the maxilla, the anatomical variation of the posterior superior alveolar nerve is commonly observed in the molar region. The average distance between the posterior superior alveolar artery and the alveolar crest was the smallest in the 2nd molar region[4]. Therefore, surgical procedures in this region may result in complications. Padovani et al. observed a higher prevalence of visualization of the posterior superior alveolar artery in males (76.7%). In the present study, the PSA variation pattern was more frequent in females on the left side. In addition, the assessment of the association between the presence of the PSA canal and the sinus disease revealed that greater prevalence of sinus diseases in women (40.8%), also in the left side[25].

The tomographic assessment of the PSA artery in the maxillary sinus region is relevant due to the possibility of hemorrhage caused by injuries in these structures during surgical procedures[4]. Moreover,

tomographical images also allow the assessment of the course of the PSA artery as intraosseous, superficial and intrasinusal[7,26]. The presence of PSA with an intrasinusal course may not be identified radiographically and require assessment using CBCT[9,26,27].

Thus, the use of cone beam computed tomography is strongly recommended to identify anatomical variations and, consequently, minimize the incidence of nervous and vascular complications. In addition, detailed tomographic evaluation provides support for the adequate positioning of implants. The identification of anatomical variations such as incisive canal, canalis sinuosus and posterior superior alveolar canal may result in changes in treatment planning such as modifications in implant positioning and location of the surgical approach[12,13].

Taken together, these data demonstrate the applicability of CBCT for the evaluation of anatomical structures[16,17]. However, some parameters must be evaluated rigorously. The size of the FOV and the size of the reconstructed voxels are parameters that can vary in different imaging protocols of the same CBCT unit. Therefore, different equipment may present variations in the visualization of anatomical structures. A large FOV with a small voxel reconstruction can generate images with a relevant noise level[28]. In this context, image quality has been widely discussed, since high quality is fundamental for the visualization of the structures and can increase the risk of diagnostic errors caused by image noise. The performance of CBCT units depends on the configuration of the parameters and their physical aspects. Thus, tomographic sections obtained with different technical parameters certainly make it difficult to compare the data. In this context, another important aspect refers to the profile of the statistical analysis carried out. Descriptive statistical analysis, such as that carried out in this study, can be considered a limitation for comparison with previous studies.

Conclusion

CBCT reliably identifies the incisive canal, canalis sinuosus, and posterior superior alveolar canal and their variations. Key findings include:

- IC septations (4.12%) and diameter changes (22.68%).
- CS alveolar extension (17.15%), predominantly right-sided.
- PSA alveolar extension (15.46%), with left-side preference in females and right-side in males.

References

1. McCrea Shane JJ. Aberrations causing neurovascular damage in the anterior maxilla during dental implant placement. Case Rep Dent. 2017 Jul: 5969643. doi: 10.1155/2017/5969643.

2. Shelley A, Tinning J, Yates J, Horner K. Potential neurovascular damage as a result of dental implant placement in the anterior maxilla. Br Dent J. 2019 May;226(9):657-661. doi: 10.1038/s41415-019-0260-4.

3. Jornet PL, Boix P, Perez AS, Boracchia A. Morphological characterization of the anterior palatine region using cone beam computed tomography. Clin Implant Dent Relat Res. 2015 Oct;17 Suppl 2: e459-64. doi: 10.1111/cid.12271.

4. Pandharbale AA, Gadgil RM, Bhoosreddy AR, Kunte VR, Ahire BS, Shinde MR, et al. Evaluation of the posterior superior alveolar artery using cone beam computed tomography. Pol J Radiol. 2016 Dec 19; 81:606-610. doi: 10.12659/PJR.899221.

5. Karslioglu H, Çitir M, Gunduz K, Kasap P. The radiological evaluation of posterior superior alveolar artery by using CBCT. Curr Med Imaging. 2021;17(3):384-389. doi: 10.2174/1573405616666200628134308.

6. Elian N, Wallace S, Cho SC, Jalbout ZN, Froum S. Distribution of the maxillary artery as it relates to sinus floor augmentation. Int J Oral Maxillofac Implants. 2005 Sep-Oct;20(5):784-7.

7. Danesh-Sani SA, Movahed A, ElChaar ES, Chan KC, Amintavakoli K. Radiographic evaluation of maxillary sinus lateral wall and posterior superior alveolar artery anatomy: A cone-beam computed tomographic study. Clin Implant Dent Relat Res. 2017 Feb;19(1):151-160. doi: 10.1111/cid.12426.

8. Sato I, Kawai T, Yoshida S, Miwa Y, Imura K, Asaumi R. Observing the bony canal structure of the human maxillary sinus in Japanese cadavers using cone beam CT. Okajimas Folia Anat Jpn. 2010 Nov;87(3):123-8. doi: 10.2535/ofaj.87.123.

9. Tehranchi M, Taleghani F, Shahab S, Nouri A. Prevalence and location of the posterior superior alveolar artery using cone-beam computed tomography. Imaging Sci Dent. 2017 Mar;47(1):39-44. doi: 10.5624/isd.2017.47.1.39.

10. Price JB, Thaw KL, Tyndall DA, Ludlow JB, Padilla RJ. Incidental findings from cone beam computed tomography of the maxillofacial region: a descriptive retrospective study. Clin Oral Implants Res. 2012 Nov;23(11):1261-8. doi: 10.1111/j.1600-0501.2011.02299. x.

11. Genç T, Duruel O, Kutlu HB, Dursun E, Karabulut E, Tözüm TF. Evaluation of anatomical structures and variations in the maxilla and the mandible before dental implant treatment. Dent Med Probl. 2018 Jul-Sep;55(3):233-240. doi: 10.17219/dmp/94303.

12. Valente NA. Anatomical considerations on the alveolar antral artery as related to the sinus augmentation surgical procedure. Clin Implant Dent Relat Res. 2016 Oct;18(5):1042-1050. doi: 10.1111/cid.12355.

13. Yusof MYPM, Mah MC, Reduwan NH, Kretapirom K, Affendi NHK. Quantitative and qualitative assessments of intraosseous neurovascular canals in dentate and posteriorly edentulous individuals in lateral maxillary sinus wall. Saudi Dent J. 2020 Dec;32(8):396-402. doi: 10.1016/j.sdentj.2019.10.010.

14. Song WC, Jo DI, Lee JY, Kim JN, Hur MS, Hu KS, et al. 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. 2009 Oct;108(4):583-90. doi: 10.1016/j.tripleo.2009.06.036.

15. Suter VGA, Warnakulasuriya S, Reichart PA, Bornstein MM. Radiographic volume analysis as a novel tool to determine nasopalatine duct cyst dimensions and its association with presenting symptoms and postoperative complications. Clin Oral Investig. 2015 Sep;19(7):1611-8. doi: 10.1007/s00784-014-1391-2.

16. Tyndall DA, Price JB, Tetradis S, Ganz SD, Hildebolt C, Scarfe WC. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012 Jun;113(6):817-26. doi: 10.1016/j.oooo.2012.03.005.

17. Bahşi I, Orhan M, Kervancıoğlu P, Yalçın ED, Aktan AM. Anatomical evaluation of nasopalatine canal on cone beam computed tomography images. Folia Morphol (Warsz). 2019;78(1):153-162. doi: 10.5603/FM. a2018.0062.

18. Kawai T, Sato I, Asaumi R, Yosue T. Cone-beam computed tomography and anatomical observations of normal variants in the mandible: variant dentists should recognize. Oral Radiol. 2018 Sep;34(3):189-198. doi: 10.1007/s11282-017-0307-7.

19. Soumya P, Koppolu P, Pathakota KR, Chappidi V. Maxillary incisive canal characteristics: a radiographic study using cone beam computerized tomography. Radiol Res Pract. 2019 Mar 27; 2019:6151253. doi: 10.1155/2019/6151253.

20. Shan T, Qu Y, Huang X, Gu L. Cone beam computed tomography analysis of accessory canals of the canalis sinuosus: A prevalent but often overlooked anatomical variation in the anterior maxilla. J Prosthet Dent. 2021 Oct;126(4):560-568. doi: 10.1016/j.prosdent.2020.05.028.

21. Anatoly A, Sedov Y, Gvozdikova E, Mordanov O, Kruchinina L, Avanesov K. Radiological and morphometric features of canalis sinuosus in Russian population: cone-beam computed tomography study. Int J Dent. 2019 Dec 16; 2019:2453469. doi: 10.1155/2019/2453469.

22. Orhan K, Gorurgoz C, Akyol M, Ozarslanturk S, Avsever H. An anatomical variant: evaluation of accessory canals of the canalis sinuosus using cone beam computed tomography. Folia Morphol (Warsz). 2018;77(3):551-557. doi: 10.5603/FM. a2018.0003.

23. Tomrukçu DN, Köse TE. Assesment of accessory branches of canalis sinuosus on CBCT images. Med Oral Patol Oral Cir Bucal. 2020 Jan 1;25(1):e124-e130. doi: 10.4317/medoral.23235.

24. Aoki R, Massuda M, Zenni LTV, Fernandes KS. Canalis sinuosus: anatomical variation or strucure? Surg Radiol Anat. 2020 Jan;42(1):69-74. doi: 10.1007/s00276-019-02352-2.

25. Anamali S, Avila-Ortiz G, Elangovan S, Qian F, Ruprecht A, Finkelstein M, Allareddy V. Prevalence of the posterior superior alveolar canal in cone beam computed tomography scans. Clin Oral Implants Res. 2015;26(1): e8-12. doi: 10.1111/clr.12318.

26. Verardi S. CT scans may not be indicated to analyze the distribution of the arteries in the lateral wall of the maxillary sinus. J Evid Based Dent Pract. 2006

Dec;6(4):276-7. doi: 10.1016/j.jebdp.2006.09.004.

27. Rosano G, Taschieri S, Gaudy JF, Weinstein T, Del Fabbro M. Maxillary sinus vascular anatomy and its relation to sinus lift surgery. Clin Oral Implants Res. 2011 Jul;22(7):711-715. doi: 10.1111/j.1600-0501.2010.02045.

28. Santos Junior O, Pinheiro LR, Umetsubo OS, Cavalcanti MGP. CBCT- based evaluation of integrity of cortical sinus close to periapical lesions. Braz Oral Res. 2015;29: S1806-83242015000100216. doi:10.1590/1807-3107BO015.vol29.0019.

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