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Original Research Article

Influence of apical periodontitis and periodontal bone loss on maxillary sinus mucosal thickening

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Abstract

Introduction and Objective: Inflammatory alterations in the maxillary sinus may arise from infections associated with periapical and periodontal bone loss in the posterior maxillary teeth. This study assessed the influence of apical periodontitis and periodontal bone loss on maxillary sinus mucosal thickening. **Material and methods:** CBCT scans of 500 patients were analyzed to investigate the relationship between apical periodontitis and periodontal bone loss on maxillary sinus mucosal thickening. Statistical analysis was conducted using the chi-square test. The association between dependent and independent variables was analyzed using robust Poisson regression models. **Results:** The patients were aged between 17 and 94 years, with an average age of 49.2 ± 11.9 years. In total, 936 posterior maxillary teeth were examined: 143 first premolars (15.2%), 238 second premolars (25.5%), 304 first molars (32.5%), and 251 second molars (26.8%). MS mucosal thickening > 2 mm was observed in 45% of the evaluated teeth (n=421). Five hundred and eight-three teeth (62.3%) had apical periodontitis with bone loss and 468 (50%) had periodontal bone loss. The frequency and degree of severity of sinus mucosal thickening was related with sex, presence

of AP, and periodontal bone loss. **Conclusion:** A positive association was observed between maxillary sinus mucosal thickening and the presence of apical periodontitis and periodontal bone loss.

Introduction

The maxillary sinus (MS), the largest of the paranasal sinuses, is located within the body of the maxilla and extends toward the zygomatic process [4]. It is the paranasal sinus most frequently associated with inflammatory and infectious conditions [4, 32]. Inflammation of the MS is commonly referred to as maxillary sinusitis [4, 27].

Inflammatory changes in the MS may originate from infections associated with the roots of the maxillary posterior teeth [3, 9, 30]. The roots of the first molars and second premolars often lie near the MS floor, sometimes protruding into the sinus and separated from its cavity by only a thin layer of bone and [4, 17, 23, 29, 32, 40]. Bacteria and toxins from dental infections can reach the sinus directly or through vascular, osseous, or lymphatic pathways, leading to mucosal infection [3, 27, 30, 37]. Approximately 10%-12% of maxillary sinusitis cases are of dental origin, which may complicate diagnosis and management for both patients and clinicians [4, 27]. Underdiagnosis or misidentification of odontogenic sinus pathology can result in persistent symptoms and contribute to treatment failure [37].

The close anatomical relationship between the maxillary posterior teeth and the maxillary sinus, along with the potential spread of associated infections, has been extensively investigated using various imaging modalities [3, 30]. Although panoramic and periapical radiographs are routinely employed in dental practice [4, 19, 39], they have notable limitations and reduced accuracy in detecting sinus–dental relationships [11, 14, 17]. Cone-beam computed tomography (CBCT) has therefore become widely used in both dentistry and medicine, providing superior precision for diagnosing infectious and inflammatory conditions [2, 6, 15, 16, 27, 36]. Previous studies have emphasized the value of CBCT in assessing the morphological characteristics of the maxillary sinus (MS) and its anatomical relationship with the roots of the upper posterior premolars and molars [3, 17, 26-29, 38]. Furthermore, significant associations have been reported between odontogenic pathologies and sinus alterations, particularly with respect to MS mucosal thickening [27, 39].

The post-processing CBCT software e-Vol DX was developed to address common limitations in CBCT imaging [7]. It provides high-resolution images with sub-millimeter voxel sizes, dynamic multi-plane navigation, and customizable volume parameters such as slice thickness and interval spacing. Advanced image enhancement tools, including brightness and contrast adjustments and various filters, allow optimized data visualization [18]. Unlike other CBCT software, e-Vol DX is compatible with all CBCT scanners and enables DICOM data export. It offers superior control over contrast, brightness, slice thickness, and sharpness, along with a sophisticated noise-reduction algorithm, predefined filter presets, and an exceptional zoom function without resolution loss. The software also supports high-resolution screen captures [5-8, 15, 18]. Additionally, e-Vol DX includes a novel CBCT measurement method using a specific filter within the platform [8]. A recent study [18] applied dynamic navigation, optimized-resolution CBCT scans, and an AI-driven enhancement filter in e-Vol DX to investigate the frequency and risk factors of maxillary sinusitis of endodontic origin. The use of these tools enhanced both the quantity and accuracy of information on associations between maxillary sinus inflammatory or infectious conditions—such as periapical mucositis, partial and total obstruction—and the posterior maxillary teeth.

Despite growing interest in the relationship between dental pathologies and maxillary sinus alterations [18], further studies are needed to clarify the association between periodontal bone loss, apical periodontitis, and MS mucosal thickening, particularly when assessed using advanced CBCT tools. Therefore, the present study aimed to provide a novel perspective by employing these tools to investigate potential associations between dental-origin pathologies, specifically apical periodontitis and periodontal bone loss with MS mucosal thickening. We hypothesized that dental-origin pathologies are associated with increased maxillary sinus mucosal thickness.

Material and methods

The sample of this retrospective study was selected from a database of a radiology clinic (CROIF

– Center for radiology and Orofacial Imaging, Cuiabá, MT, Brazil) and consisted of CBCT scans of patients referred for different diagnostic reasons and taken between January 2015 and December 2020. The sample size was based on a previous study [1]. Using a confidence level of 95%, a margin of error of 5%, and an expected proportion of 50%, the minimum estimated sample size was 411 subjects. Sample size calculation was performed using G*Power version 3.1.2 software (Heinrich Heine, Universität Düsserdorf, Düsseldorf, Germany). This study was approved by the Institutional Ethics Committee of the Research Committee (#06486919.0.0000.5083).

Inclusion criteria for CBCT scans were the presence of first or second premolars, and first or second maxillary molars with fully formed root apices and eruptions, with or without endodontic treatment, apical periodontitis, periodontal bone loss, and MS mucosal thickening. Exclusion criteria included CBCT scans showing orthodontic appliances, teeth with inflammatory resorption, bone alterations associated with systemic disorders, or benign and/or malignant tumors in the maxilla or maxillary sinus.

CBCT scans were acquired using a PreXion 3D scanner (Prexion 3D Inc., San Mateo, CA, USA) following a standard protocol: slice thickness = 0.100 mm; dimensions = 1,170 × 1,570 × 1,925 mm; FOV = 56.00 mm; voxel size = 0.108 mm; exposure time = 37 s (16 bits); tube voltage = 90 kVp; and tube current = 4 mA. Images were reconstructed using the Prexion Scanner software and exported as multifile DICOM images, which were subsequently processed using e-Vol DX software (CDT Software; São José dos Campos, SP, Brazil) on a PC workstation equipped with an Intel i7-7700K processor (4.20 GHz), NVIDIA GeForce GTX 1070 graphics card, Dell P2719H monitor (1920 × 1080 pixels), and Windows 10 Pro (Microsoft Corp., Redmond, WA, USA).

The CBCT exams were standardized so that the MS was aligned from the axial point of view. The sagittal and coronal planes were utilized to orient the long axis of the sample transversely to the ground, aiming to correct for parallax errors. The evaluation of the MS mucosal thickness was performed in healthy teeth, teeth with apical periodontitis and teeth with periodontal bone loss. For this purpose, a specific filter of measures recently developed was used [8].

The criteria used in the present study for examining the occurrence of MS mucosal thickness and related variables were as follows: 1. Maxillary sinus membrane thickness: (0) normal (thickness up to 2 mm), (1) thickness from 2.1 to 5 mm, (2) thickness above 5.1 mm [37]. For measurement, a straight line was drawn from the lowest bone point of the MS floor to the most superior point of the maxillary sinus mucosa; 2. Apical periodontitis: (0) absent (regular periapical appearance and unharmed periodontal ligament region and lamina dura) or (1) present [radiographic alterations in the periapical area (alterations in the periodontal ligament region, loss of lamina dura integrity, or mild to severe alterations in bone changes with well-defined hypodense areas]) [37]; 3. Periodontal bone loss: (0) normal to mild (<1/3 alveolar bone loss), (1) moderate (1/3 to 2/3 alveolar bone loss), (2) severe (>2/3 alveolar bone loss). These data were categorized into the presence or absence of periodontal bone loss [22].

For measurements, the plane showing the greatest extent of sinus membrane thickening was used as the reference. The condition of each tooth was evaluated in all CBCT planes, navigating from cervical to apical regions and vice versa. When multiple teeth or roots were associated with apical periodontitis, the most severely affected one was recorded.

All analyses were performed by two observers (an endodontist and a radiologist) with over 10 years of experience in CBCT interpretation. The observers were calibrated prior to the study by evaluating 10% of the CBCT sample. All assessments were repeated twice, with a 30-day interval between evaluations.

Statistical analysis

All statistical evaluation was accomplished using the SPSS for Windows version 15.0 software (SPSS Inc., Chicago, IL, USA). Associations between variables were determined by means of the chi-square test. A significant level of $p<0.05$ was considered statistically significant. Poisson regression analysis was applied to verify the association between dependent and independent variables using robust models; for these model significance levels of $p<0.05$ or $p<0.20$ were adopted. The adjusted model included the variables that were considered significant ($p<0.05$). Interexaminer agreement was evaluated using Cohen's kappa coefficient (k).

Results

Interexaminer agreement was almost perfect ($k>0.81$). The study sample consisted of 500 CBCT scans of patients of both sexes. The patients were

aged between 17 and 94, with an average of 49.2 ± 11.9 years. A total of 936 posterior maxillary teeth were analyzed: 143 first premolars (15.2%), 238 second premolars (25.5%), 304 first molars (32.5%), and 251 second molars (26.8%). Of the total analyzed teeth, 544 belonged to female participants (58.1%) and 392 belonged to male participants (41.9%). MS mucosal thickening > 2 mm was observed in 45% of the evaluated teeth (n=421). 583 teeth (62.3%) had apical periodontitis and 468 (50%) had periodontal bone loss. There were statistically significant associations between the occurrence and severity of MS mucosal thickening and all the variables studied (p<0.05), with exception for age (p=0.236) (table I). Analysis of non-adjusted and adjusted associations is presented in table II. After adjustments, sex, presence/absence of AP and presence/absence of periodontal bone loss were independently associated with MS mucosal thickness (table II).

Table I – Prevalence of maxillary sinus mucosal thickness according to gender, age, apical periodontitis and periodontal bone loss (n=936)

Variable / Category	**Maxillary sinus mucosal thickness**				
	up to 2 mm	2.1-5 mm	≥ 5.1 mm	Total	p value*
Sex					
Female	331 (35.4%)	147 (15.7%)	66 (7.1%)	544 (58.1%)	<0.001
Male	184 (19.7%)	129 (13.8%)	79 (8.4%)	392 (41.9%)	
Age					
17-30 years old	42 (4.5%)	13 (1.4%)	6 (0.6%)	61 (6.5%)	0.236
31-50 years old	260 (27.8%)	142 (15.2%)	72 (7.7%)	474 (50.6%)	
≥ 51 years old	213 (22.8%)	121 (12.9%)	67 (7.2%)	401 (42.8%)	
Apical periodontitis					
Absence	265 (28.3%)	64 (6.8%)	24 (2.6%)	353 (37.7%)	<0.001
Present	250 (26.7%)	212 (22.6%)	121 (12.9%)	583 (62.3%)	
Periodontal bone loss					
Absence	293 (31.3%)	107 (11.4%)	68 (7.3%)	468 (50.0%)	<0.001
Present	222 (23.7%)	169 (18.1%)	77 (8.2%)	468 (50.0%)	

* Chi-square

Table II – Estimated prevalence ratio (PR) and confidence interval (CI) for maxillary sinus mucosal thickness in the non-adjusted and adjusted Poisson regression analysis (n = 936)

Variable / Category	Non-adjusted PR (95% CI)	p-value[a]	Adjusted PR (95% CI)	p-value[b]
Sex				
Female	1		1	
Male	1.35 (1.11-1.64)	0.002	1.32 (1.15-1.51)	<0.001
Age				
17-30 years old	1		1	
31-50 years old	1.44 (0.98-2.13)	0.060	1.12 (0.77-1.63)	0.530
≥ 51 years old	1.50 (1.02-2.21)	0.039	1.02 (0.69-1.48)	0.918
Apical periodontitis				
Absent	1		1	
Present	2.29 (1.88-2.78)	<0.001	2.20 (1.81-2.68)	<0.001
Periodontal bone loss				
Absence	1		1	
Presence	1.40 (1.21-1.62)	<0.001	1.24 (1.07-1.43)	0.003

[a] Poisson regression with robust (non-adjusted) models; [b] Poisson regression with robust (adjusted) models

Discussion

Advances in implant therapy, bone grafting procedures, and endodontic techniques have increased both the frequency and complexity of dental procedures performed near the maxillary sinus (MS) [21, 22]. Nevertheless, the proximity of odontogenic factors to the MS has contributed to the development of inflammatory and/or infectious alterations, which can be difficult to diagnose [25]. Post-processing CBCT analysis revealed positive correlations between apical periodontitis, periodontal bone loss, and maxillary sinus mucosal thickening. Accordingly, the study hypothesis was confirmed.

In the present study, MS mucosal thickening was observed in 45% of cases, closely aligning with the 46.6% reported by Gomes *et al.* [20] and the 48.4% reported by Lu *et al.* [27]. Ritter *et al.* [34] documented a lower prevalence of 38.1%, whereas Shanbhag *et al.* [37] reported a higher rate of 60.5%. These discrepancies likely reflect methodological differences among studies, including variations in sample size, diagnostic criteria, participant selection, and measurement techniques [10, 12, 13, 20-25, 27, 33-35, 37]. This heterogeneity underscores the need for standardized protocols in future research to enhance the comparability and reliability of findings regarding MS mucosal alterations.

A total of 936 posterior maxillary teeth were analyzed in this study, of which 544 (58.1%) belonged to female participants and 392 (41.9%) to male participants. A significant proportion of maxillary sinuses with mucosal thickness ≥ 5.1 mm was observed in male subjects (n = 79; 54.6%). This finding is consistent with previous studies by Shanbhag *et al.* [37] and Huang *et al.* [22], but contrasts with the results reported by Khorramdel *et al.* [24]. Gomes *et al.* [20] found that women were 2.04 times less likely than men to develop maxillary changes. These gender differences in mucosal thickening may result from a complex interplay of social, economic, environmental, and biological factors influencing health outcomes.

The presence or absence of MS mucosal thickening can be evaluated based on different established criteria [22, 33]. White and Pharoah [40] suggested that sinus mucosal thickening exceeding 3 mm indicates pathology in the MS. Maillet *et al.* [28] proposed CBCT-based diagnostic criteria for sinusitis, defining the condition as a mass with soft tissue density, represented by mucosal thickening greater than 2 mm. Nunes *et al.* [29] assessed the impact of periapical lesions in posterior maxillary teeth on the MS using CBCT, diagnosing MS mucosal thickening when a non-corticalized area with soft tissue density, thickness >3 mm, and parallel to the sinus bony wall was observed.

Variations in diagnostic criteria make comparisons across challenging studies [22, 37]. In this study, sinus membrane thickness was classified using a modified system based on Shanbhag *et al*. [37], who investigated correlations between teeth affected by apical periodontitis or periodontal bone loss and MS mucosal thickening on CBCT scans.

In the present study, mucosal thickening was more frequently observed in the MS of patients with posterior teeth affected by periapical pathology, consistent with previous findings [3, 18, 22, 24, 27, 29, 32, 34, 37, 39]. Maxillary sinuses with periapical lesions are estimated to have 2.3 to 10.2 times higher odds of exhibiting alterations compared to those without lesions [37, 39]. Furthermore, the likelihood of sinus alterations increases proportionally with the size of the periapical lesion [27]. The proximity of apical periodontitis to the MS has also been identified as a factor influencing the degree of sinus mucosal irritation [19, 21, 39]. Bacteria and toxins from periapical inflammatory processes can infiltrate the MS directly or via vascular anastomoses, porous alveolar bone, or lymphatic pathways, leading to mucosal infection [3, 27, 30, 37].

In addition to the infectious process associated with the root canal, periodontal disease may also contribute to the development of sinus pathologies [24, 35]. de Lima *et al*. [10] observed that patients with tooth mobility and periodontal bone loss in the posterior maxillary teeth exhibited 3.45 times higher risk of developing maxillary sinusitis. Among the various factors studied, periodontal bone loss showed a positive association with SM mucosal thickening, as was also observed previously [10, 24, 35]. It has been suggested that quantities of bacteria and inflammatory cytokines are considerably augmented in areas with marginal periodontitis and that these products can achieve the MS mucosa by direct diffusion through porous maxillary bone, leading to inflammation and thickening of the MS mucosa [10]. However, Eggmann *et al*. [13] evaluated the relationship between periapical and periodontal diseases in the posterior area of the maxilla and the appearance of the sinus mucous membrane, reporting that the current evidence is inconclusive regarding the influence of periodontal disease on the occurrence of changes in the Schneiderian membrane. In previous study [31], it has been shown that there is an 82% risk of having an odontogenic type of maxillary sinus mucosal thickening with the presence of AP partially demineralized towards the sinus floor. More thickening of the maxillary sinus mucosa is seen with larger AP lesions and partial demineralization of the sinus floor.

The way the roots of the maxillary premolars and molars relate to the MS, both horizontally and vertically, may be a predictive factor for the dissemination of odontogenic infections into the MS, as changes in the alveolar bone cortex, mainly the vestibular cortex, are common in the presence of infections originating in maxillary teeth [3, 30]. Additionally, the tooth apex may not only be in contact with the MS floor but also protruded into its interior [17, 25, 26]. Estrela *et al*. [17] evaluated in the Brazilian subpopulation the vertical connection between the MS floor and the roots of the first and second molars, observing that the type II relationship (sinus floor situated below the level connecting the apices of the buccal and palatal roots) was the most common. On the other hand, Kwak *et al*. [26] and Kilic *et al*. [25] observed high frequencies of the type I relationship (sinus floor situated above the level connecting the apices of the buccal and palatal roots). It is important to note that both type I and II vertical relationships have in common the absence of root protrusion into the maxillary sinus interior, which is a rare condition [12, 38].

The analysis conducted in this study was retrospective and based on the review of CBCT scans from a database of a private clinic. Although retrospective studies are relatively easy and economical to conduct, they have the limitation of the inability to establish a clear temporal relationship to prove cause-effect relationships since the data are collected at the same time [22, 37]. In addition, this study was restricted by the addition of only those suspected maxillary sinusitis patients with mucosal thickening. It's important to highlight that some participants with maxillary sinusitis may not present with mucosal thickening or related sinus fluid. Thus, conducting new studies, with longitudinal assessments could contribute to a better understanding of the relationship between increased thickness of the MS membrane and demographic and clinical variables.

Conclusion

A positive association was observed between maxillary sinus mucosal thickening and the presence of apical periodontitis and periodontal bone loss.

References

1. Altwaijri A, Kolarkdoi SH, Alotaibi KZ, Alotaiby F, Almutairi FJ. Retrospective CBCT analysis of maxillary sinus pathology prevalence in the Saudi Arabian population. Saudi Dent J. 2024;36:868-72.

2. Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofac Radiol. 1999;28:245-8.

3. Ariji Y, Obayashi N, Goto M, Izumi M, Naitoh M, Kurita K et al. Roots of the maxillary first and second molars in horizontal relation to alveolar cortical plates and maxillary sinus: computed tomography assessment for infection spread. Clin Oral Investig. 2006;10:35-41.

4. Brook I. Sinusitis of odontogenic origin. Otolaryngol Head Neck Surg. 2006;135:349-55.

5. Bueno MR, Azevedo BC, Estrela CRA, Sousa-Neto MD, Estrela C. Method to identify accessory root canals using a new CBCT software. Braz Dent J. 2021;32:28-35.

6. Bueno MR, Estrela C, Azevedo BC, Cintra Junqueira JL. Root canal shape of human permanent teeth determined by new cone-beam computed tomographic software. J Endod. 2020;46:1662-74.

7. Bueno MR, Estrela C, Azevedo BC, Diogenes A. Development of a new cone-beam computed tomography software for endodontic diagnosis. Braz Dent J. 2018;29:517-29.

8. Bueno MR, Estrela CRA, Granjeiro JM, Sousa-Neto MD, Estrela C. Method to determine the root canal anatomic dimension by using a new cone-beam computed tomography software. Braz Dent J. 2019;30:3-11.

9. Cymerman JJ, Cymerman DH, O'Dwyer RS. Evaluation of odontogenic maxillary sinusitis using cone-beam computed tomography: three case reports. J Endod. 2011;37:1465-9.

10. de Lima CO, Devito KL, Baraky Vasconcelos LR, Prado MD, Campos CN. Correlation between endodontic infection and periodontal disease and their association with chronic sinusitis: a clinical-tomographic study. J Endod. 2017;43:1978-83.

11. Durack C, Patel S. Cone beam computed tomography in endodontics. Braz Dent J. 2012;23:179-91.

12. Eberhardt JA, Torabinejad M, Christiansen EL. A computed tomographic study of the distances between the maxillary sinus floor and the apices of the maxillary posterior teeth. Oral Surg Oral Med Oral Pathol. 1992;73:345-6.

13. Eggmann F, Connert T, Buhler J, Dagassan-Berndt D, Weiger R, Walter C. Do periapical and periodontal pathologies affect Schneiderian membrane appearance? Systematic review of studies using cone-beam computed tomography. Clin Oral Investig. 2017;21:1611-30.

14. Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. J Endod. 2008;34:273-9.

15. Estrela C, Costa MVC, Bueno MR, Rabelo LEG, Decurcio DA, Silva JA et al. Potential of a new cone-beam ct software for blooming artifact reduction. Braz Dent J. 2020;31:582-8.

16. Estrela C, Couto GS, Bueno MR, Bueno KG, Estrela LRA, Porto OCL et al. Apical foramen position in relation to proximal root surfaces of human permanent teeth determined by using a new cone-beam computed tomographic software. J Endod. 2018;44:1741-8.

17. Estrela C, Nunes CA, Guedes OA, Alencar AH, Estrela CR, Silva RG et al. Study of anatomical relationship between posterior teeth and maxillary sinus floor in a subpopulation of the brazilian central region using cone-beam computed tomography – part 2. Braz Dent J. 2016;27:9-15.

18. Estrela CRA, Bueno MR, Estrela MRA, Estrela LRA, Guedes OA, Azevedo BC et al. Frequency and risk factors of maxillary sinusitis of endodontic origin evaluated by a dynamic navigation and a new filter of cone-beam computed tomography. J Endod. 2022;48:1263-72.

19. Garcia B, Penarrocha M, Marti E, Martinez JM, Gay-Escoda C. Periapical surgery in maxillary premolars and molars: analysis in terms of the distance between the lesion and the maxillary sinus. J Oral Maxillofac Surg. 2008;66:1212-7.

20. Gomes AEDN, Bueno CEDS, Martin AS, Stringheta CP, Fontana CE, Rocha DGP etal. Association of maxillary sinus reactions and periapical pathology in the maxillary posterior teeth: evaluation using cone beam computed tomography. Braz Dent J. 2024;35:e245973.

21. Hauman CH, Chandler NP, Tong DC. Endodontic implications of the maxillary sinus: a review. Int Endod J. 2002;35:127-41.

22. Huang YT, Hu SW, Huang JY, Chang YC. Assessment of relationship between maxillary sinus membrane thickening and the adjacent teeth health by cone-beam computed tomography. J Dent Sci. 2021;16:275-9.

23. Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH. The analysis of maxillary sinus aeration according to aging process; volume assessment by 3-dimensional reconstruction by high-resolutional CT scanning. Otolaryngol Head Neck Surg. 2005;132:429-34.

24. Khorramdel A, Shirmohammadi A, Sadighi A, Faramarzi M, Babaloo AR, Sadighi Shamami M et al. Association between demographic and radiographic characteristics of the schneiderian membrane and periapical and periodontal diseases using cone- beam computed tomography scanning: a retrospective study. J Dent Res Dent Clin Dent Prospects. 2017;11:170-6.

25. Kilic C, Kamburoglu K, Yuksel SP, Ozen T. An assessment of the relationship between the maxillary sinus floor and the maxillary posterior teeth root tips using dental cone-beam computerized tomography. Eur J Dent. 2010;4:462-7.

26. Kwak HH, Park HD, Yoon HR, Kang MK, Koh KS, Kim HJ. Topographic anatomy of the inferior wall of the maxillary sinus in Koreans. Int J Oral Maxillofac Surg. 2004;33:382-8.

27. Lu Y, Liu Z, Zhang L, Zhou X, Zheng Q, Duan X et al. Associations between maxillary sinus mucosal thickening and apical periodontitis using cone-beam computed tomography scanning: a retrospective study. J Endod. 2012;38:1069-74.

28. Maillet M, Bowles WR, McClanahan SL, John MT, Ahmad M. Cone-beam computed tomography evaluation of maxillary sinusitis. J Endod. 2011;37:753-7.

29. Nunes CA, Guedes OA, Alencar AH, Peters OA, Estrela CR, Estrela C. Evaluation of periapical lesions and their association with maxillary sinus abnormalities on cone-beam computed tomographic images. J Endod. 2016;42:42-6.

30. Obayashi N, Ariji Y, Goto M, Izumi M, Naitoh M, Kurita K et al. Spread of odontogenic infection originating in the maxillary teeth: computerized tomographic assessment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004;98:223-31.

31. Oliveira-Santos N, Leite AF, Petitjean E, Torres A, Van der Veken D, Curvers F et al. The relation between Schneiderian membrane thickening and radiodiagnostic features of periapical pathology. Braz Dent J. 2024;35:e245775.

32. Penarrocha-Oltra S, Soto-Penaloza D, Bagan-Debon L, Bagan JV, Penarrocha-Oltra D. Association between maxillary sinus pathology and odontogenic lesions in patients evaluated by cone beam computed tomography. A systematic review and meta-analysis. Med Oral Patol Oral Cir Bucal. 2020;25:e34-e48.

33. Rege IC, Sousa TO, Leles CR, Mendonca EF. Occurrence of maxillary sinus abnormalities detected by cone beam CT in asymptomatic patients. BMC Oral Health. 2012;12:30.

34. Ritter L, Lutz J, Neugebauer J, Scheer M, Dreiseidler T, Zinser MJ et al. Prevalence of pathologic findings in the maxillary sinus in cone-beam computerized tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;111:634-40.

35. Roque-Torres GD, Ramirez-Sotelo LR, Vaz SL, Boscolo SM, Boscolo FN. Association between maxillary sinus pathologies and healthy teeth. Braz J Otorhinolaryngol. 2016;82:33-8.

36. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am. 2008;52:707-30.

37. Shanbhag S, Karnik P, Shirke P, Shanbhag V. Association between periapical lesions and maxillary sinus mucosal thickening: a retrospective cone-beam computed tomographic study. J Endod. 2013;39:853-7.

38. Sharan A, Madjar D. Correlation between maxillary sinus floor topography and related root position of posterior teeth using panoramic and cross-sectional computed tomography imaging. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006;102:375-81.

39. Vallo J, Suominen-Taipale L, Huumonen S, Soikkonen K, Norblad A. Prevalence of mucosal abnormalities of the maxillary sinus and their relationship to dental disease in panoramic radiography: results from the Health 2000 Health Examination Survey. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;109:e80-7.

40. White SC, Pharaoh MJ. Oral radiology: principles and interpretation. 2000.