EGYPTIAN
DENTAL JOURNAL

Vol. 64, 1305:1314, April, 2018

I.S.S.N 0070-9484

Oral Medicine, X-Ray, Oral Biology and Oral Pathology

www.eda-egypt.org • Codex : 210/1804

CORRELATION BETWEEN GINGIVAL BIOTYPE, MARGINAL BONE LOSS, PERIAPICAL INFECTION AND SCHNEIDERIAN MEMBRANE THICKNESS IN CHRONIC PERIODONTITIS PATIENTS (A CROSS-SECTIONAL STUDY USING CONE-BEAM COMPUTED TOMOGRAPHY ANALYSIS)

Ola M. Ezzatt [*], Fatma H. El Demerdash[*] *and* Mostafa S. Ashmawy [**]

ABSTRACT

Background: Identification of factors affecting maxillary sinus membrane thickness would be of practical importance in surgical planning for both implant placement and otolaryngeal surgery. This study aimed to analyze a possible correlation between Schneiderian membrane thickness (**SMT**) and gingival biotype **(GB)**, marginal bone loss **(MBL)** and presence of periapical infection (**PAI**) of related teeth using Cone beam computed tomography (**CBCT**)

Subjects and Methods: A total of fifty consecutive moderate to severe chronic periodontitis patients were included in this cross-sectional study. The patients' sex and age were recorded. Clinical measurement of (**GB**) was performed in the premolar and first molar area, and then **(CBCT)** images of patients were examined for **(SMT)**, **(MBL)** and presence of **(PAI)** in the same area. All measured parameters were analyzed and graded. Then correlation between these parameters and Schneiderian membrane thickness was evaluated.

Results: Higher percentage of severe SMT was observed in patient with thick gingival biotype (37.3%) than those with thin biotype (33.3%) and a direct positive correlation between SMT and MBL (r= 0.595, $p<0.001$) was detected. Cases with PAI showed higher mean sinus membrane thickness (5.3±1.97) than normal cases (2.26±1.90) ($p<0.001$).

Conclusion: The presence of periapical infection marginal bone loss or clinically detected thick gingival biotype in the maxilla could be associated with thicker Schneiderian membrane, so clinicians should be aware of these clinical and radiographic findings that could predict the sinus membrane thickness.

KEYWORDS: CBCT, Schneiderian membrane, gingival biotype, marginal bone loss, periapical infection.

* Lecturer of Oral Medicine, Oral Diagnosis and Periodontology, Faculty of Dentistry, Ain Shams University
** Lecturer of Oral Radiology, Faculty of Dentistry, Ain Shams University

INTRODUCTION

The close anatomic proximity of the maxillary sinus to the alveolar crest makes dental disease, especially periodontal diseases and periapical lesions a potential source for the spread of the infection into the maxillary sinuses[1]. The sinus is lined with a thin respiratory mucous membrane referred as the Schneiderian membrane which adheres to the periosteum and is about one millimeter thick[2].

When the sinus mucosa comes to be irritated membrane thickness greater than 3 mm is most likely observed that appear in radiographic image as a non-corticated radiopaque band, paralleling the bony wall of the sinus. It is considered a sign of sinusitis and possible pathologic entities in the sinus[3]. Sinus pathologies and certain medications may alter membrane thickness[4]. Apical periodontitis, periodontal diseases implant treatment and tooth extraction are thought to increase the odds of maxillary sinusitis[5,6]. However data regarding anatomical factors that may affect thickness of healthy sinus mucosa is limited[7].

Detailed information about the maxillary sinus anatomy and its anatomic variations is required in precise surgery including implant placement and sinus lifting procedures to prevent complications in the maxillary posterior area[8]. It is difficult to visualize important maxillary sinus anatomic areas adjacent to the roots of molars due to the superimposition of the adjacent structures[9]. However cone beam computed tomography (**CBCT**) is a three dimensional (**3D**) imaging modality that is effective in revealing the etiology and relationship between odontogenic pathologic lesions and sinus involvement[10].

Recently, Aimetti et al and Deepthi et al reported that gingival thickness seems to represent a reliable parameter to predict sinus membrane thickness[7,11]. While Khorramdel et al and Goller-Bulut et al found that membrane thickness was significantly associated with marginal bone loss, apical lesions, and they all recommended further investigations[10,12].

The aim of the present study was to assess the relation between sinus Schneiderian membrane thickness and gingival biotype, the presence of periapical lesions and marginal bone loss using CBCT among chronic periodontitis patients.

PATIENTS AND METHODS

Patient's Selection

Fifty consecutive patients scheduled for Phase I therapy were recruited from the outpatient clinic of Oral Medicine, Periodontology, Oral Diagnosis and Oral Radiology department at Faculty of Dentistry, Ain Shams University.

Both genders with age range (30-60 years) and free from any systemic disease were selected based on the following criteria: **(1)** Existence of at least second premolar and 1st molar in maxillary left or right sides (fully erupted teeth and fully formed apices) **(2)** Clinically diagnosed with moderate to severe chronic periodontitis in maxillary premolar and molar area with clinical attachment loss (**CAL**) more than three millimeters[13]. Pregnant females, smokers or patients taking medication that may induce gingival enlargement as well as patients who had signs of acute infections or those with history of developmental anomalies, previous trauma or surgery involving the sinus or gingiva were excluded.

The study was designed as cross sectional study and the protocol has been performed in accordance with the ethical standards laid down in the Declaration of Helsinki. The selected sites in eligible patients were examined clinically and radiographically using cone beam computed tomography (CBCT) after patients' agreement and the following measurements were recorded;

Clinical Measurements

All measurements were recorded by an expert periodontist blinded to the radiographic measurements using University of Michigan O probe with William's markings ***(Hu-Friedy***

Mfg. Co., LLC, UK). Gingival biotype was clinically recorded based on the transparency of the periodontal probe through the gingival margin while probing the sulcus at the mid-facial aspect of teeth at the premolar and molar area; if the outline of the underlying periodontal probe could be seen through the gingiva, it was categorized as ***Thin GB*** (**Figure 1A**) and if not, it was categorized as ***Thick GB*** on a site based level (**Figure 1B**)[14].

Radiographic Measurements

All patients were referred for CBCT examination at the Oral Radiology Department, Faculty of Dentistry, Ain-Shams University. The image acquisition was performed using i-CAT next generation ***(Imaging sciences international, Hatfield, PA, USA)*** with exposure parameters 120 kVp, 5 mA, 0.2 mm voxel size, 26 seconds scanning time and field of view was limited to the maxillary arch. **DICOM** (digital images and communication in medicine) files were transferred to a third party software; OnDemad3D ***(Cybermed, Seoul, South Korea).***

An oral radiologist with 14 years of experience examined the images twice separated by two weeks interval. Images were viewed in a dimmed light room on a computer monitor 17 inch HD LED ***(Dell Inc., Berkshire, UK).*** Reconstructed panoramic images were created by drawing the panoramic curve on the axial image (**Figure 2A**), and then cross sectional images were created parallel to the long axis of the tooth having periodontal defect (**Figure 2B**). Image enhancement was done using the sharpness filter tool to increase the image sharpness by a factor of

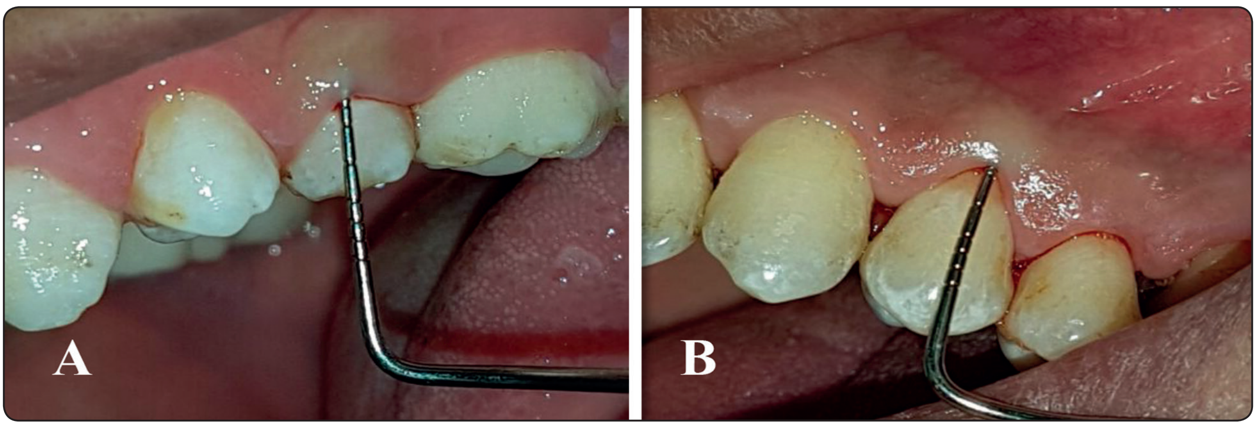

Fig. (1) Photo showing examination of gingival biotype A. Thin gingiva and B. Thick gingiva

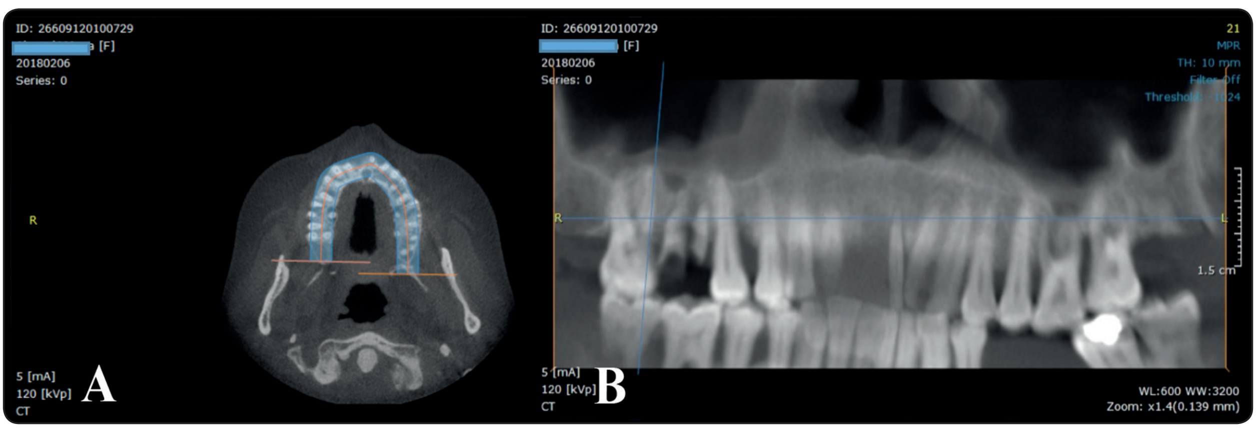

Fig. (2) A. Axial image showing the determination of reconstructed panoramic curve B. Reconstructed panoramic image showing the alignment of cross sectional line parallel to the long axis of the examined tooth one (Filter X1), also image brightness and contrast was adjusted accordingly for each case. All the following parameters were assessed on the cross sectional images:

Periapical infection [Yes/No]

The presence of bone resorption related to the apex of the examined tooth was recorded as a periaipcal infection **(PAI) (Figure 3A)**.

Schneiderian Membrane Thickness [mm]

Schneiderian Membrane Thickness **(SMT)** was measured at the point of maximum thickness from the sinus floor. The measurement was performed on the cross sectional images using the "measurement tool" provided by the software and was expressed in millimeters. The observer performed three measurements apical to each examined tooth, then the mean thickness was calculated **(Figure 3B).** The SMT was recorded as: **Normal** if the thickness was ≤ 1mm; **Mild** if the thickness was 1-2 mm; **Moderate** if the thickness was 2-4 mm; **Severe** if the thickness was 4-10 mm; and **Extensive** if the thickness was more than 10 mm[2].

Marginal Bone loss [MBL (mm)]

MBL was measured as the distance between the cemento-enamel-junction (**CEJ**) and the alveolar bone crest at the buccal aspect of the examined tooth, and then two millimeters were deducted from this measurement. Several measurements were taken at different mesiodistal positions then the highest measurement was chosen for statistical analysis **(Figure 3B)**.

Statistical Analysis

Numerical data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed non-normal (non-parametric) distribution. Data were represented by mean, standard deviation (SD), median and range values. Spearman's correlation coefficient was used to determine significant correlations between different quantitative variables. Mann-Whitney U test was used to compare between sinus membrane thickness in cases with or without periapical infection. Qualitative data were presented as frequencies and percentages. Fisher's Exact test was used to determine the association between sinus membrane thickness grade and presence of periapical infection as well as sinus membrane thickness grade and gingival biotype. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM® ***(IBM Corporation, NY, USA),*** SPSS® Statistics Version 20 for Windows ***(SPSS, Inc., an IBM Company).***

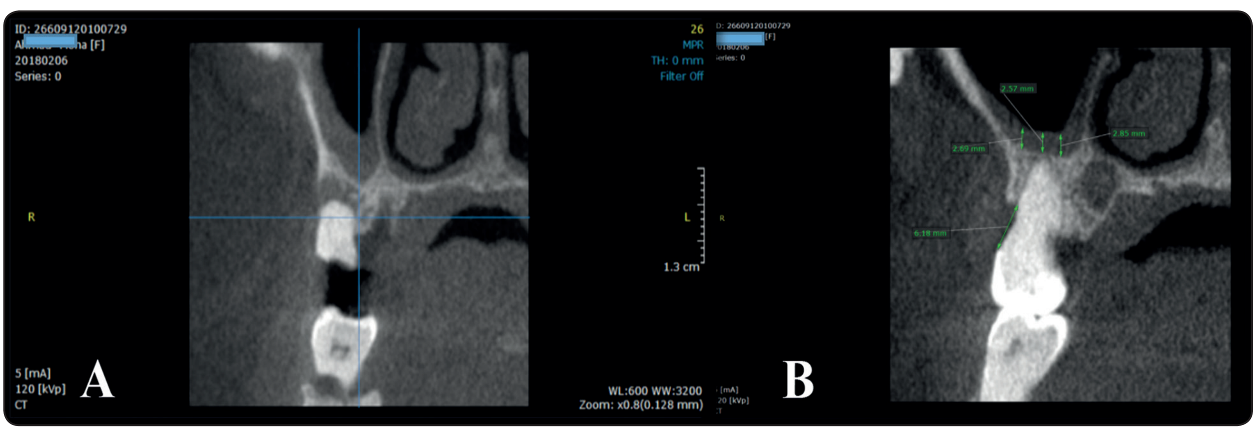

Fig. (3) Reconstructed cross sectional images showing A. The presence of periapical infection B. The measurement of MBL and SMT

RESULTS

The present study was conducted on 50 subjects; 33 females (66%) and 17 males (34%) with no significant difference regarding sex distribution among the study population. Their mean age was 44.4 ± 9.3 years with a minimum of 31 years and a maximum of 58 years old.

The clinical examination revealed that 29 patients (58%) had thick gingival biotype while 21 patients (42%) had thin biotype with no statistical difference between the distribution of these two types among the chronic periodontitis patients.

The mean MBL as measured in CBCT in the chronic periodontitis patients included in this study was 2.8±1.14 with a minimum of 1mm and a maximum of 5.9mm. While the mean SMT was 2.9±2.3 ranged from 0.5mm to 7.9mm (32% was Normal, 16% Mild, 16% Moderate, 36% Severe, and no extensive membrane thickness was found); no significant statistical difference was observed between percentage of normal, mild to moderate and severe SMT among the study population. Periapical infection was detected only in 12 patients (24%).

Table 1 represents the association between SMT grades and gingival biotype in which higher percentage of severe thickness of sinus membrane was observed in patient with thick gingival biotype (37.3%) than those with thin biotype (33.3%) as well as normal thickness grade while opposite was observed in moderate and severe grades but without statistical significant differences between percentage of the two gingival biotypes in each grade of sinus membrane thickness.

Correlation analysis of the results demonstrated that there was a statistically significant direct (positive) correlation between SMT and MBL (r= 0.595, p<0.001) **(Figure 4).** Cases with periapical infection showed statistically significant higher mean sinus membrane thickness (5.3±1.97) than normal cases (2.26±1.90) (p<0.001). Moreover, cases with severe sinus membrane thickness grade showed the highest prevalence of periapical infection (83.3%) while no case in this study with normal sinus membrane thickness grade showed periapical infection with statistical significant differences between percentage of cases with and without PAI in each SMT Grade **(Table 2)**.

TABLE (1): Frequencies, percentages and results of Fisher's Exact test for the association between sinus membrane thickness (SMT) grade and gingival thickness

SMT Grade	Thick gingiva (n = 29)		Thin gingiva (n = 21)		*P*-value
	n	%	n	%	
Normal	11/29	37.9	5/21	23.8	0.464
Mild	4/29	13.8	4/21	19	
Moderate	3/29	10.3	5/21	23.8	
Severe	11/29	37.9	7/21	33.3	

TABLE (2): Frequencies, percentages and results of Fisher's Exact test for the association between sinus membrane thickness (SMT) grade and presence of periapical infection

SMT Grade	Periapical infection (n = 12)		Normal (n = 38)		*P*-value
	n	%	n	%	
Normal	0/12	0	16/38	42.1	0.001*
Mild	1/12	8.3	7/38	18.4	
Moderate	1/12	8.3	7/38	18.4	
Severe	10/12	83.3	8/38	21.1	

: Significant at $P \leq 0.05$

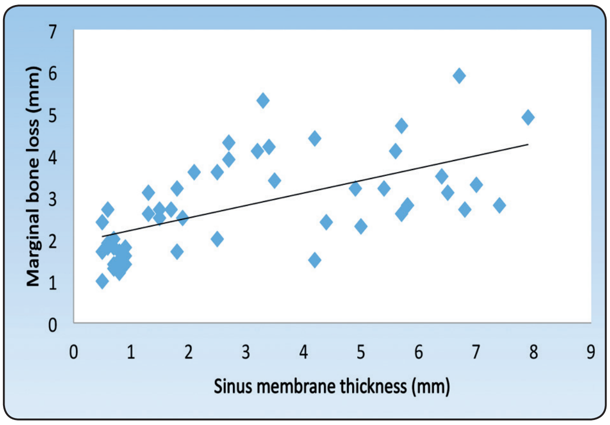

Fig. (4) Scatter diagram representing direct correlation between sinus membrane thickness and marginal bone loss

DISCUSSION

The study attempted to clarify the possible association between maxillary sinus Schneiderian membrane thickness and marginal bone loss, gingival biotype and presence of periapical infection in chronic periodontitis patients that may help the clinicians to predict the membrane thickness and minimize complications during sinus left procedure[15]. Patients within the same age range and periodontal disease severity and with no difference in sex distribution were included while smokers were excluded to minimize the effect of these confounding factors on sinus membrane thickness as recently reported by Maska et al. and Khorramdel et al. in 2017[10,16].

In the present study we choose to use CBCT for radiographic evaluation of the periodontal defects due to its ability to reconstruct 3D images allowing the radiologist to gain information regarding the defect dimensions and association with maxillary floor in contrast to the 2D techniques[17–19]. In addition, software features allow reorientation of cross sectional images in planes other than axial, coronal or sagittal sections in order to easily detect PAI or to accurately measure MBL and SMT[20,21].

Several studies investigated the maxillary sinus using computed tomography (CT)[22,23], on the other hand CBCT provides the same information regarding 3D reconstructed images and linear measurement accuracy with an enormous reduction in patient absorbed dose[24–27]. Regarding the relationship between PAI and maxillary sinus our choice to use CBCT was in accordance with Cymerman et al.[28] and Nurbakhsh et al.[29] **.**

For evaluation of gingival biotype we used a simple and reproducible method which is the transparency of the periodontal probe through the gingival margin. And because tissue biotype was also correlated to and can predict the gingival thickness and underlying bone thickness[30].

A recent meta-analysis reported overall mean of SMT (1.17±0.1 mm) in CBCT[15]. However, the mean SMT in this study was 2.9±2.3 ranged from 0.5mm to 7.9mm. In accordance with the study conducted by Janner et al and evaluated 168 CBCT images; the thickness of the Schneiderian membrane exhibited variable thickness in CBCT with highest mean values, ranging from (2.16 to 3.11 mm) However the wide range obtained in his study (0.16-34.61mm) may be explained by the presence of other confounding factors as age, gender and periodontal diseases[31].

In this study we reported that 32% of sinus membrane was Normal, 16% Mild, 16% Moderate, 36% Severe, and no extensive membrane thickness. While other study by Maska et al evaluated 29 CBCT scans found that 93.1% of them had maxillary sinus mucosal thickening. Specifically, 6.9% of cases exhibited no thickening, 6.9% had minimal thickening, 20.7% of cases had moderate thickening, and 65.5% had severe thickening[16]. This was more than what was reported in our study for chronic periodontitis patients; a total of 68% of patients exhibited mucosal thickness × 1mm but the contradiction in results may be attributed to un excluded confounding factors.

The mean MBL as measured in CBCT in the chronic periodontitis patients included in this study was 2.8±1.14 with a minimum of 1mm and a maximum of 5.9mm with a strong significant direct correlation between SMT and MBL which was consistent with the previous studies[32,33]. Janner et al. also found that there is an association between the SMT and MBL[31]. The similarity of the results of these studies with the present study can be due to the similar methods of research. The association between bone loss in periodontal diseases and sinus mucosal thickness was further emphasized in Ren et al. study in 2015 who found that among the 221 periodontal patients studied, 103 (48.9%) displayed SMT and also reported dramatic increase in SMT with the degree of alveolar bone loss[34]. Phothikhun in et al. also demonstrated a three-fold increase in the likelihood of SMT with severe periodontitis[33]. Sheiki et al later concluded that there is an association between both MBL and pulpoperiapical condition and SMT, but the effect of MBL was about 4 times stronger[35].

The previous finding is also supported and explained by histopathological study by Moskow that found direct relationship between moderate and severe periodontitis of the maxillary molar teeth and pathological changes resulting in maxillary sinus mucosal thickening[36]. Furthermore maxillary sinus floor is perforated by a number of vessels, allowing for close approximation of the maxillary sinus mucosa and periodontal ligament and the separation consists only of mucoperiosteum in some individuals[37]. Thus overlap between collateral branches of posterior superior alveolar arteries representing main blood supply of the dental and periodontal structures with the basilar maxillary sinus vascular network may also encourage the spread of periodontal inflammation to sinus[38].

Aimitti et al. in 2008 investigated the correlation between gingival phenotype and Schneiderian membrane and found that mean SMT was 1.26±0.14 mm in individuals with thick gingival compared to 0.61±0.15 mm in subjects with thin gingival tissues and recommended the use of gingival thickness as reliable parameter to predict sinus membrane thickness[39], Deepthi et al in 2012 later reported a strong correlation between SMT and GB[7]. The previous results were in accordance with higher percentage of severe thickness of sinus membrane in thick biotype patients observed in our study. These results may be attributed to the previous finding that biotype is significantly related to underlying bone thickness and alveolar crest position[40,41], and that the SMT is also correlated to residual ridge height[42].

In the present study, the presence of periapical infection was associated with severe SMT in 83.3% of the cases, consistent with the results of a study by Bolger et al. in which 83.2% of the cases had thick membrane thickness in the presence of periapical infection[42]. In comparison, this percentage was reported to be 38.1% in a study by Ritter et al.[43], 48.4% in a study by Lu et al.[44], and 60% in a study by Hähnel et al.[45]. However, the discrepancies between the results of studies might be attributed to differences in race or age and the different diagnostic techniques used. The proximity of periapical pathosis and the sinus floor may be a potential factor of sinus mucosal irritation and subsequent thickening[46,47].

This study has demonstrated that clinical and radiographic findings as the presence of periapical infection marginal bone loss or clinically detected thick gingival biotype can predict the presence of thick Schneiderian membrane, so may help clinicians in planning their sinus left procedure in chronic periodontitis patients. However, number of limiting factors diminished the impact of our results; including small number of patients and single center design. In addition, other clinical changes evaluation as gingival index and clinical signs of sinusitis would have revealed more confounding factors and help to understand the association.

REFERENCES

1. Savolainen S, Eskelin M, Jousimies-Somer H, Ylikoski J. Radiological findings in the maxillary sinuses of symptomless young men. Acta Otolaryngol Suppl. 1997; 529:153–7.
2. Lu Y, Liu Z, Zhang L, Zhou X, Zheng Q, Duan X. Associations between Maxillary Sinus Mucosal Thickening and Apical Periodontitis Using Cone-Beam Computed Tomography Scanning: A Retrospective Study. J Endod. 2012 38:1069–74.
3. Rak KM, Newell JD, Yakes WF, Damiano MA, Luethke JM. Paranasal sinuses on MR images of the brain: significance of mucosal thickening. Am J Roentgenol 1991;156:381–4.
4. Melén I, Lindahl L, Andréasson L, Rundcrantz H. Chronic maxillary sinusitis. Definition, diagnosis and relation to dental infections and nasal polyposis. Acta Otolaryngol 1986;101:320–7.
5. Abrahams JJ, Glassberg RM. Dental disease: a frequently unrecognized cause of maxillary sinus abnormalities? AJR Am J Roentgenol. 1996;166:1219–23.
6. van den Bergh JP, ten Bruggenkate CM, Disch FJ, Tuinzing DB. Anatomical aspects of sinus floor elevations. Clin Oral Implants Res. 2000;11:256–65.
7. Deepthi BC, Shetty S, Satish Babu CL, Rohit P, Mallikarjuna DM, Bharat Raj R.Correlation between Gingival Phenotype , Residual Ridge Height and the Schneiderian Membrane. Int J Oral Implantol Clin Res 2012;3(3): 111-115.2012;3:111–5.
8. Beretta M, Cicciù M, Bramanti E, Maiorana C. Schneider Membrane Elevation in Presence of Sinus Septa: Anatomic Features and Surgical Management. Int J Dent 2012;2012:1–6.
9. Tack D, Widelec J, De Maertelaer V, Bailly J-M, Delcour C, Gevenois PA. Comparison Between Low-Dose and Standard-Dose Multidetector CT in Patients with Suspected Chronic Sinusitis. Am J Roentgenol. 2003;181:939–44.
10. 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.
11. Aimetti M, Massei G, Morra M, Cardesi E, Romano F. Correlation between gingival phenotype and Schneiderian membrane thickness. Int J Oral Maxillofac Implants 2008;23:1128–32.
12. Goller-Bulut D, Sekerci AE, Köse E, Sisman Y. Cone beam computed tomographic analysis of maxillary premolars and molars to detect the relationship between periapical and marginal bone loss and mucosal thickness of maxillary sinus. Med Oral Patol Oral Cir Bucal. 2015;20:e572–9.
13. Armitage GC. Development of a Classification System for Periodontal Diseases and Conditions. Ann Periodontol 1999;4:1–6.
14. Malhotra R, Grover V, Bhardwaj A, Mohindra K. Analysis of the gingival biotype based on the measurement of the dentopapillary complex. J Indian Soc Periodontol 2014;18:43–7.
15. Monje A, Diaz KT, Aranda L, Insua A, Garcia-Nogales A, Wang H-L. Schneiderian Membrane Thickness and Clinical Implications for Sinus Augmentation: A Systematic Review and Meta-Regression Analyses. J. Periodontol. 2016;888–99.
16. Maska B, Lin G-H, Othman A, Behdin S, Travan S, Benavides E, et al. Dental implants and grafting success remain high despite large variations in maxillary sinus mucosal thickening. Int J Implant Dent. 2017;3:1.
17. Janner SFM, Caversaccio MD, Dubach P, Sendi P, Buser D, Bornstein MM. Characteristics and dimensions of the Schneiderian membrane: a radiographic analysis using cone beam computed tomography in patients referred for dental implant surgery in the posterior maxilla. Clin Oral Implants Res. 2011;22:1446–53.
18. Tadinada A, Fung K, Thacker S, Mahdian M, Jadhav A, Schincaglia G Pietro. Radiographic evaluation of the maxillary sinus prior to dental implant therapy: A comparison between two-dimensional and three-dimensional radiographic imaging. Imaging Sci Dent. 2015;45:169–74.
19. Vandenberghe B, Jacobs R, Yang J. Diagnostic validity (or acuity) of 2D CCD versus 3D CBCT-images for assessing periodontal breakdown. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104:395–401.
20. Kasikcioglu A, Gulsahi A. Relationship between maxillary sinus pathologies and maxillary posterior tooth periapical pathologies. Oral Radiol. 2016;32:180–6.

21. Kamburoğlu K, Kiliç C, Ozen T, Horasan S. Accuracy of chemically created periapical lesion measurements using limited cone beam computed tomography. Dentomaxillofac Radiol. 2010;39:95–9.

22. Shahbazian M, Xue D, Hu Y, van Cleynenbreugel J, Jacobs R. Spiral computed tomography based maxillary sinus imaging in relation to tooth loss, implant placement and potential grafting procedure. J oral Maxillofac Res. 2010;1:e7.

23. Drumond JPN, Allegro BB, Novo NF, de Miranda SL, Sendyk WR. Evaluation of the Prevalence of Maxillary Sinuses Abnormalities through Spiral Computed Tomography (CT). Int Arch Otorhinolaryngol. 2017;21:126–33.

24. Li G. Patient radiation dose and protection from cone-beam computed tomography. Imaging Sci Dent. 2013;43:63.

25. Loubele M, Bogaerts R, Van Dijck E, Pauwels R, Vanheusden S, Suetens P, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol. 2009;71:461–8.

26. Liang X, Jacobs R, Hassan B, Li L, Pauwels R, Corpas L. A comparative evaluation of Cone Beam Computed Tomography (CBCT) and Multi-Slice CT (MSCT) Part I. On subjective image quality. Eur J Radiol. 2010;75:265–9.

27. Suomalainen A, Kiljunen T, Käser Y, Peltola J, Kortesniemi M. Dosimetry and image quality of four dental cone beam computed tomography scanners compared with multislice computed tomography scanners. Dentomaxillofacial Radiol. 2009;38:367–78.

28. 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.

29. Nurbakhsh B, Friedman S, Kulkarni G V, Basrani B, Lam E. Resolution of maxillary sinus mucositis after endodontic treatment of maxillary teeth with apical periodontitis: a cone-beam computed tomography pilot study. J Endod. 2011;37:1504–11.

30. De Rouck T, Eghbali R, Collys K, De Bruyn H, Cosyn J. The gingival biotype revisited: transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva. J Clin Periodontol. 2009;36:428–33.

31. Janner SFM, Caversaccio MD, Dubach P, Sendi P, Buser D, Bornstein MM. Characteristics and dimensions of the Schneiderian membrane: a radiographic analysis using cone beam computed tomography in patients referred for dental implant surgery in the posterior maxilla. Clin Oral Implants Res. 2011;22:1446–53.

32. 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.

33. Phothikhun S, Suphanantachat S, Chuenchompoonut V, Nisapakultorn K. Cone-beam computed tomographic evidence of the association between periodontal bone loss and mucosal thickening of the maxillary sinus. J Periodontol. 2012;83:557–64.

34. Ren S, Zhao H, Liu J, Wang Q, Pan Y. Significance of maxillary sinus mucosal thickening in patients with periodontal disease. Int Dent J. 2015;65:303–10.

35. Shahidi S, Samiri B, Kyani F, Panahi R. Evaluation of the Association of Sinus Mucosal Thickening with Dental and Periodontal Status Using Cone Beam Computed Tomographic Imaging. Journal of Dentomaxillofacial Radiology, Pathology and Surgery. 2016;5(2):33-9.

36. Moskow BS. A histomorphologic study of the effects of periodontal inflammation on the maxillary sinus mucosa. J Periodontol. 1992;63:674–81.

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

38. Moskow BS, Polson AM. Histologic studies on the extension of the inflammatory infiltrate in human periodontitis. J Clin Periodontol. 1991;18:534–42.

39. Aimetti M, Massei G, Morra M, Cardesi E, Romano F. Correlation between gingival phenotype and Schneiderian membrane thickness. Int J Oral Maxillofac Implants.2008;23:1128–32.

40. Fu J-H, Yeh C-Y, Chan H-L, Tatarakis N, Leong DJM, Wang H-L. Tissue Biotype and Its Relation to the Underlying Bone Morphology. J Periodontol. 2010;81:569–74.

41. Cook DR, Mealey BL, Verrett RG, Mills MP, Noujeim ME, Lasho DJ. Relationship between clinical periodontal biotype and labial plate thickness: an in vivo study. Int J Periodontics Restorative Dent. 2011;31:345–54.

42. Yilmaz HG, Tözüm TF. Are Gingival Phenotype, Residual Ridge Height, and Membrane Thickness Critical for the Perforation of Maxillary Sinus? J Periodontol 2012;83:420–5.

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

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

45. Hähnel S, Ertl-Wagner B, Tasman AJ, Forsting M, Jansen O. Relative value of MR imaging as compared with CT in the diagnosis of inflammatory paranasal sinus disease. Radiology. 1999;210:171–6.

46. Nunes CABCM, Guedes OA, Alencar AHG, Peters OA, Estrela CRA, 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.

47. 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. Oral Surgery, Oral Med Oral Pathol Oral Radiol Endodontology. 2010;109:e80–7.