Journal of the International Academy of Periodontology 2013 **15/3**:75-82

Is the Schneiderian Membrane Thickness Affected by Periodontal Disease? A Cone Beam Computed Tomography-based Extended Case Series

Dorothea C. Dagassan-Berndt[1], Nicola U. Zitzmann[2], J. Thomas Lambrecht[1], Roland Weiger[2] and Clemens Walter[2,3]

[1]Department of Oral Surgery, Oral Radiology and Oral Medicine, School of Dentistry, University of Basel, Switzerland
[2]Department of Periodontology, Endodontology and Cariology, School of Dentistry, University of Basel, Switzerland
[3]Department of Oral Surgery, School of Dentistry, University of Birmingham, United Kingdom

Abstract

Objective: The aim was to assess the thickness of Schneiderian membranes (SM) in patients with advanced periodontal disease. **Methods:** 17 dentate patients (DG) scheduled for periodontal surgery on maxillary molars were consecutively recruited and cone beam computed tomographies performed for preoperative diagnosis. Twenty-one patients (EG) requiring cone beam computed tomography-based planning of implant placement in the edentulous posterior maxilla served as controls. **Results:** Schneiderian membrane thickness measured from cone beam computed tomography was significantly greater in the dentate group compared to the edentulous group, both in the first ($p = 0.028$) and second ($p < 0.001$) molar position. In the dentate group, clinical signs of periodontal destruction (increased probing pocket depth or furcation involvement) were not associated with Schneiderian membrane thickness. Additional findings, such as periapical lesions ($p = 0.008$), and the distance between root tips and maxillary sinus revealed a significant association ($p = 0.036$) with Schneiderian membrane thickness. **Conclusion:** In molar regions with periodontal destruction, Schneiderian membrane thickening occurred, particularly in combination with small bone layers above the root tips or periapical lesions.

Key words: Cone beam computed tomography, furcation involvement, Schneiderian membrane, membrane swelling, maxillary sinus

Introduction

An inflammation of the Schneiderian membrane (SM) covering the paranasal sinus is referred to as "maxillary sinusitis" (Incaudo *et al.*, 1998). Potential etiologic factors of maxillary sinusitis include odontogenic conditions, rhinogenous pathologies, traumatic injuries, allergies and carcinogenic diseases (Arias-Irimias *et al.*, 2010). Odontogenic origins are related to periodontal and/or endodontic infections and account for approximately 10-12% of the cases of maxillary sinusitis (Brook, 2006). Cone beam computed tomography (CBCT) images potentially provide useful information regarding changes in the maxillary sinus resulting from odontogenic infections (Nair *et al.*, 2010). However, the literature reveals little data on the location and extension of Schneiderian membrane thickening based on CBCT findings (Brüllmann *et al.*, 2011; Janner *et al.*, 2011; Maillet *et al.*, 2011; Pazera *et al.*, 2011).

Periodontal diseases are prevalent chronic infectious diseases affecting primarily the tooth supporting structures (Page and Kornman 1997), and potentially deteriorating systemic health (Tonetti *et al.,* 2007; De Pablo *et al.*, 2009; Sun *et al.*, 2011). The disease occurs often in a symmetrical pattern and is more pronounced in the maxillary posterior region (Mombelli *et al.,* 2001). As soon as periodontal attachment loss is initiated, maxillary molars have the highest risk for disease progression because of their complex morphology with multiple roots, root fusion or root proximity and furcation entrances difficult to access with self-performed oral hygiene (Walter *et al.*, 2010a). Enhanced biofilm accumulation in the area of the furcation entrance leads to advanced inflammation, possibly causing horizontal and vertical periodontal destruction with furcation involvement (FI) in multi-rooted teeth.

It has been observed that the pneumatisation of the paranasal sinuses increases with age. The maxillary

Correspondence to:
Prof. Dr. Nicola U. Zitzmann, PhD
Department of Periodontology, Endodontology and Cariology
University of Basel Hebelstrasse 3, 4056 Basel (Switzerland)
Tel.:+41-61-267 2625 Fax:+41-61-267 2659
Email:n.zitzmann@unibas.ch

sinuses, in particular, extend into the area of the maxillary alveolar bone, so that the roots of maxillary molars and/or bicuspids project into the floor of the sinus as small conical processes (Gray, 1970). The close anatomical relationship between maxillary molars and the sinus floor possibly contributes to the spread of inflammatory processes from teeth and the periodontium into the maxillary sinuses, potentially contributing to atypical odontalgia and temporomandibular pain (Logan and Blocklebank, 1999). These processes possibly affect later implant placement because of a reduction in the amount of maxillary alveolar bone height and residual sinus infection, particularly when sinus augmentation is planned.

Cone beam computed tomography (CBCT) was introduced to dentistry several years ago (Mozzo *et al.*, 1998). It has been clinically validated for the assessment of furcation invasion in maxillary molars (Walter *et al.*, 2010b). It was demonstrated that CBCT enables an exact estimation and classification of the furcation involvement and a visualization of decisive features, such as root proximities, root fusions or periapical lesions (Walter *et al.,* 2009; Walter *et al.* 2010b). Further, a variation in the thickness of the sinus membrane was observed in the CBCT scans, and it was assumed that a correlation exists between sinus membrane swelling and periodontal destruction, including furcation involvement, of maxillary molars.

The aim of this study was to analyze the thickness of the Schneiderian membrane (SM) using CBCT in patients with advanced periodontal destruction in the distal maxillary area and to compare these data with edentulous regions.

Material and methods

Subject

Seventeen dentate patients (DG) diagnosed for generalized advanced or severe chronic periodontal disease were consecutively recruited for the current study during April 2007 and January 2010 from the pool of patients at the Department of Periodontology, Endodontology and Cariology. Periodontal diagnosis was based on complete dental and periodontal examinations (including sensitivity testing of all teeth, probing pocket depth (PPD), probing attachment level (PAL), furcation involvement (FI), and radiographic examinations (periapical radiographs) (Walter *et al.,* 2009). Patients had undergone periodontal pre-treatment and non-surgical periodontal therapy (scaling and root planing), and had residual PPD of $\geqslant 6$ mm and/or advanced FI at the 6-month reevaluation, indicating the need for periodontal surgery in the maxillary region. Advanced furcation involvement was defined as horizontal interradicular loss of periodontal tissues of degree II or III (Hamp *et al.,* 1975). Cone-based computed tomography was performed on the posterior maxilla for detailed preoperative diagnosis and planning of the surgical intervention.

Twenty-one patients (EG) who required CBCT-based planning of implant placement in the edentulous posterior maxillary area (free-end situations), served as control and were recruited from the Department of Oral Surgery, University of Basel, Switzerland. Tomography was performed at least eight weeks after tooth extraction in the posterior maxilla.

The study was approved by the Ethics Research Committee of the University of Basel Switzerland (EK: 279/09). Patients were thoroughly informed about the study and the methods applied and gave their informed consent. From the 38 patients enrolled, a total of 44 CBCT scans were analyzed (20 from DG and 24 from EG). Patients with a history of any bone disease (including osteoporosis), bisphosphonate intake, oroantral fistula and inflammation or previous surgery affecting the maxillary sinus were excluded.

Analyses of dental CBCTs

Cone-based computed tomography scans were performed in the posterior maxillary area using the high resolution imaging system 3D Accuitomo 60 and 3D Accuitomo 80 (Morita, Kyoto, Japan). Cylindrical volumes of 4 x 4 cm, 6 x 6 cm and 8 x 8 cm, settings in the range of 74–90 kV, 5–8 mA and voxel size of 0.125 mm (2 lp/mm) were used depending on the region of interest. All images were analyzed with the same monitor (Viewmedic 19C, 48 cm, 19°, Totoku, Japan). The software i-Dixel-3DX (Morita, Kyoto, Japan) with a linear measurement tool and a digital magnification lens was used. It facilitated a continuous motion with the cursor in the 3-dimensional area visualized in the three planes on the computer screen.

Images were analyzed in the horizontal (axial), sagittal and/or transverse (coronal) sections. All measurements were performed twice by one of the authors (D.D.B.) within one week, and an intra-class correlation coefficient (ICC) was determined to compare the repeated measurements of membrane thickness (Shrout and Fleiss, 1979). An ICC of 0.99 was calculated, revealing a high similarity of the measurements.

In DG, the following parameters were analyzed from CBCT (*Figure 1a-e*): i) the horizontal dimension of furcation involvement (*Figure 1a;* Walter *et al.,* 2009); ii) the dimension of vertical furcation involvement (*Figure 1b;* Tarnow and Fletcher, 1984); iii) the minimal bone height above each root tip to the sinus floor (*Figure 1c*); iv) the bone height in the interfurcal region defined as minimal distance of the interradicular alveolar bone crest to the sinus floor (*Figure 1d*); v) the mucous membrane (SM) thickness in second premolar, first molar and second molar sites (*Figure 1e*); vi) additional radiographic findings, including periapical lesions, combined periodontal-endodontic lesions and other findings, such as root perforation, fenestration defects,

Table 1. Evaluation of factors possibly influencing Schneiderian membrane thickness (log transformed data) in the dentate group (DG) and edentulous group (EG).

Group	Comparison	Geometric mean ratio	Lower 95%CI	Upper 95% CI	*p*-value
Dentate (DG)					
	Age	1.023	0.987	1.06	00.206
	Smoker vs never smoked	0.636	0.303	1.33	60.221
	Former smoker vs never smoked	1.269	0.313	5.141	0.729
	History of inflammation: yes/no	0.576	0.189	1.752	0.317
	Additional findings present: yes/no	2.688	1.321	5.469	0.008
	RpP vs RpC	2.104	1.711	2.588	<0.0010
	RpFM vs RpC	6.487	5.278	7.972	< 0.00
	RpSM vs RpC	6.286	5.115	7.725	<0.001
Edentulous (EG)					
	Age	0.755	0.589	0.967	0.033
	Smoker vs never smoked	0.008	0	0.687	0.039
	Former smoker vs never smoked	0.065	0.001	3.655	0.142
	Additional findings present: yes/no	0.966	0.108	8.619	0.969
	RpP vs RpC	3.238	2.303	4.553	< 0.001
	RpFM vs RpC	3.672	2.611	5.163	< 0.001
	RpSM vs RpC	1.846	1.313	2.596	< 0.001

CI, confidence interval; RpC, control reference point at the medial sinus wall; RpP, sinus membrane thickness in premolar region; RpFM, sinus membrane thickness in first molar region; RpSM, sinus membrane thickness in second molar region.

missing buccal/palatal bone plate, or overfill of the root canal.

Horizontal dimensions of furcation involvement

The horizontal furcation involvement (FI) was calculated in the horizontal (axial) plane by measuring the distance between the outer root surface and the interradicular bone to the nearest millimeter (Walter *et al.,* 2009). Furcation involvement was graduated according to Hamp *et al.* (1975). Degree 0: no horizontal loss of periodontal tissue support, i.e., no radiolucency in the furcation area. Degree I: horizontal loss of periodontal tissue support up to 3 mm. Degree II: horizontal loss of support exceeding 3 mm, but no "through and through" destruction. Degree III: horizontal "through and through" – destruction of the periodontal tissue in the furcation

Dimension of vertical furcation involvement

The assessment of the vertical dimension of FI was performed with a modified classification according to Tarnow and Fletcher (1984), and the maximal distance between the roof of the furcation and the interradicular alveolar bone crest was measured. If possible, two measurements, i.e., in the sagittal and in the transverse (coronal) plane, were performed and combined for further analyses.

Bone height between root tips and sinus floor

The images were re-sliced in order to get an orthogonal examination plane through the respective tooth. By scrolling through the volume, the tip of each root was located in the transverse (coronal) and sagittal plane. The shortest distance between each root tip and the sinus floor was estimated.

SM thickness at second premolar, first molar and second molar sites

In the centerline of each tooth position (second premolar, first molar and second molar), the most caudal point of the sinus was identified in the sagittal plane. The distance from the sinus floor to the top of SM was measured. In case of an interfering septum, the centerline was moved slightly to a more distal position.

The examination of the CBCT scans in the edentulous control group (EG) included: i) measurement of the vertical thickness of SM; ii) minimal alveolar bone height; iii) recording of additional findings such as metal-like radiopaque material in the alveolar bone crest or in the SM, a visible lamina dura of the alveolus after tooth extraction.

SM thickness at second premolar, first molar and second molar sites

In the sagittal plane the most caudal position of the sinus floor was identified and marked as reference point Rp1 (*Figure 2*). An imaginary reference point Rp2 was defined 1.5 cm above and perpendicular to Rp1. A horizontal line from Rp2 to the medial sinus wall defined RpC, which served as a control reference point apart from the alveolar bone and teeth. From RpC, a perpendicular line was drawn downwards, which

Table 2. Comparison of Schneiderian membrane (SM) thickness in dentate versus edentulous sites according to tooth positions (means of log transformed data)

Position	Geometric mean ratio	Lower 95% CI	Upper 95% CI	*p*-value
RpC	0.839	0.445	1.583	0.587
RpP	0.659	0.35	1.24	0.196
RpFM	2.031	1.08	3.822	0.028
RpSM	3.37	1.791	6.342	<0.001

CI, confidence interval; RpC, control reference point at the medial sinus wall; RpP, sinus membrane thickness in premolar region; RpFM, sinus membrane thickness in first molar region; RpSM, sinus membrane thickness in second molar region

Table 3. Evaluation of the influence of clinical parameters on SM thickness in the dentate group

Factor	Geometric mean ratio	Lower 95% CI	Upper 95% CI	*p*-value
PPD	0.983	0.588	1.643	0.943
PPD % $\geqslant$ 6 mm	0.7	0.041	2.169	0.796
FI	1.122	0.685	1.836	0.631
% $\geqslant$ FI 2	1.061	0.234	4.819	0.935
Distance from root to sinus	1.492	1.031	2.159	0.036
Minimal distance from alveolar bone crest to sinus floor	1.137	0.947	1.365	0.157
Intrafurcal bone loss	1.196	0.929	1.538	0.154

FI, furcation involvement; PPD, probing pocket depth

served as a reference plane. Perpendicular to this reference plane, three measurement points were constructed, which represented the position of the second maxillary premolar (RpP) at an average distance of 0.5 cm, the first molar (RpFM) at a distance of 1.3 cm, and the second molar (RpSM) at a distance of 2.1 cm. Then the transverse (coronal) plane was used to measure the thickness of the SM by dropping a perpendicular from the most caudal point of the sinus floor to the top of the membrane at RpP, RpFM and RpSM. For comparison the thickness of the membrane was also measured at RpC. Further, the vertical alveolar bone height between the alveolar bone crest and the sinus floor was measured at the respective points (*Figure 3*). All reference points used in the current study were defined and validated in preliminary settings.

Minimal alveolar bone height

The minimal vertical distance from the alveolar bone crest to the sinus floor was determined by scrolling through the scan in the transverse (coronal) and sagittal plane. The most caudal point of the maxillary sinus was identified and a perpendicular line was dropped caudal to the bone crest. The mean of both measurements in the sagittal and transverse planes was calculated and used for further analyses.

Statistical analysis

For the comparison of categorical variables counts and percentages were detected. Corresponding *p*-values were calculated by Fisher's exact test. Metric variables (e.g., age) were reported as means with standard deviation (SD). A Student's *t*-test was used for comparisons between groups (DG and EG). The level of significance was set at $\alpha = 0.05$. Because of the non-normal distribution of the values of SM thickness, zero values were replaced by the smallest feasible value (here 0.1) in order to obtain a log-normal distribution. Log transformed data of SM thickness were used for further analyses. Mixed effects models were used to investigate the influence of factors possibly affecting SM thickness at a specific tooth site. While the respective tooth site was taken as random effect, age, smoking categories, medical history, additional findings and clinical parameters were defined as fixed effects. Nested models were performed to analyse SM thickness separately for groups or locations. Geometric mean ratios and 95% confidence limits were calculated from the corresponding back transformed contrasts of the mixed effect models. To analyze a potential effect of clinical parameters among DG, PPD means and percentage of PPD $\geqslant$ 6 mm were calculated for each tooth site; FI means and percentage of FI $\geqslant$ 2 were determined accordingly. All analyses were performed with R version 2.9.2 (R Development Core Team 2009, Vienna, Austria).

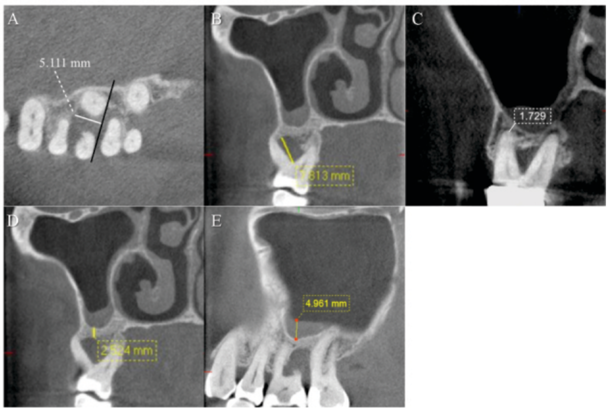

Figure 1. Measurements performed in dentate subjects (DG): a) Assessment of the horizontal dimension of furcation involvement; b) Measurement of the dimension of vertical furcation involvement; c) Measurement of the minimal bone height above each root tip to the sinus floor; d) Assessment of the minimal distance of the interradicular alveolar bone crest to the sinus floor; e) Measurement of the mucous membrane thickness in a first molar site.

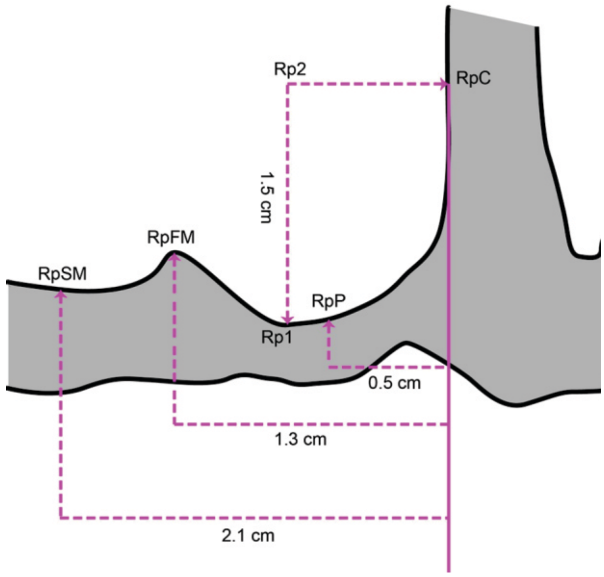

Figure 2. Reference points for analysis of mucous membrane thickness in the maxillary sinus in the edentulous control group (EG). RpC, control reference point at the medial sinus wall; RpP, sinus membrane thickness in premolar region; RpFM, sinus membrane thickness in first molar region; RpSM, sinus membrane thickness in second molar region.

Results

Demographic data of the study population

The DG comprised six women and 11 men with a mean age of 56.5 ± 8.5 years. Ten patients reported to be non-smokers, one patient was a former smoker and six were current smokers. The EG comprised 13 women and eight men with a mean age of 67.9 ± 7.7 years. Sixteen patients were partially edentulous and five patients were completely edentulous in the maxilla. Four patients had never smoked, two patients were former smokers, and three were current smokers. In 12 patients, no information was available regarding their smoking status.

The sex distribution, history of inflammation in the maxillary sinus or smoking status were similar among subjects in the DG and EG, while EG subjects were more likely to be older than DG subjects (p < 0.001, Table 1). Additional findings observed from CBCT analyses were more likely to be present in the dentate group (p = 0.009).

SM thickness in the DG and EG

Schneiderian membrane thickness varied between 1.90 ± 2.68 mm (premolar), 3.65 ± 2.54 mm (1st molar) and 3.25 ± 2.25 mm (2nd molar) among the three tooth positions in the DG, and between 2.99 ± 3.91 mm (premolar), 2.72 ± 3.31 (1st molar) and 1.68 ± 2.56 (2nd molar) among the three corresponding reference points in the EG (*Figure 4*). Mean SM thickness at the control reference point RpC at the medial sinus wall measured 0.80 ± 1.09 mm in the DG, and 1.39 ± 1.97 mm in the EG. In both groups, data of log transformed SM thickness at the defined tooth positions differed significantly from RpC (*Table 1*). In the area of the first (RpFM) and second (RpSM) maxillary molars, SM thickness was significantly greater in DG than in EG (*Figure 4* and *Table 2*). In the medial area of the sinus (RpC) and at the second premolar position (RpP), no group differences were observed.

Association of clinical parameters or anatomical factors with SM in the DG

None of the clinical parameters (PPD and FI), or vertical bone loss within the furcal area, showed an association with SM thickness (*Table 3*). While the alveolar bone height was not related to the SM thickness (p = 0.157), the distance of the root tips to the maxillary sinus revealed a significant association with smaller bone distances accompanying thicker sinus membranes (p = 0.036).

Association of systemic factors with SM thickness in DG and EG

Although no association between the systemic factors age or current smoking and SM thickness was found in DG, these factors were significantly associated with an increased SM thickness in EG (*Table 1*). Conversely, the presence of additional findings was significantly associated with an increased SM thickness in DG (p = 0.008).

Discussion

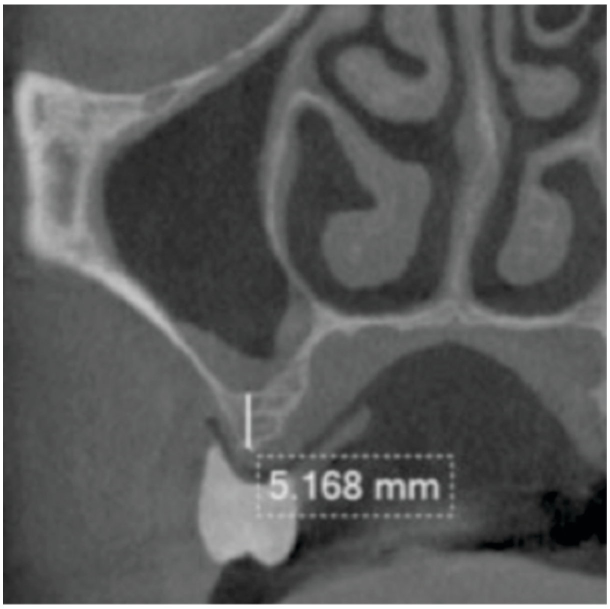

Figure 3. Measurement of minimal distance of alveolar bone crest to the sinus floor in a subject in the edentulous group (EG).

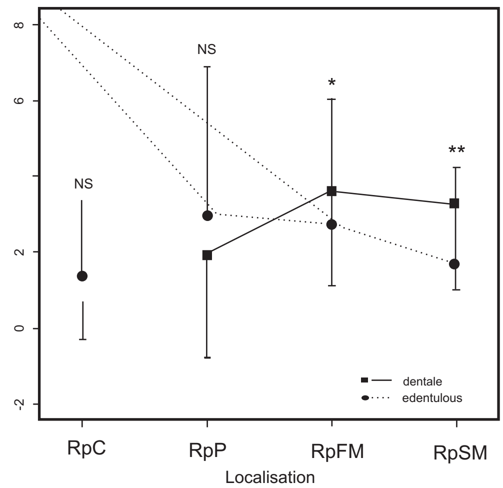

Figure 4. Comparison of Schneiderian membrane (SM) thickness in dentate and edentulous sites (means ± standard deviations). NS, not significant; *p = 0.028; **p < 0.001; RpC, control reference point at the medial sinus wall; RpP, sinus membrane thickness in premolar region; RpFM, sinus membrane thickness in first molar region; RpSM, sinus membrane thickness in second molar region

The present case series indicated that the thickness of the Schneiderian membrane is affected by periodontally diseased maxillary molars as compared to edentulous areas. Although small bone layers separating the root tips from the sinus floor were associated with increased SM thickness, no clear relation was determined for the clinical periodontal parameters.

The evaluation of the association of furcation-involved teeth with sinus membrane thickness was carried out as a retrospective analysis in a series of cases. The basic principles of ALARA (as low as reasonably achievable) on the use of CBCT of the European Academy of Dentomaxillofacial Radiology were implemented in the current study. All CBCT examinations were justified for each patient in order to add significant information for subsequent treatment (EADMFR Guidelines 2011; Horner *et al.,* 2011). Because of the restricted indications for CBCT scans, the sample size was small and subjects requiring CBCT scans for implant planning were used as controls. This control group was defined so as to have tooth extraction performed in the posterior maxilla at least two months previously. The time period of two months was assumed to be sufficient for consolidation of the alveolus and re-establishing sound membrane conditions no longer affected by previous teeth or tooth conditions. Because landmarks identifying tooth regions were no longer present, corresponding reference points had to be constructed. When considering the present study design aimed at investigating the thickness of Schneiderian membranes (SM) in patients with advanced periodontal disease, alternative designs would comprise a follow-up study before and after periodontal treatment, or a comparison with a healthy control group with sound dentitions. Ethical concerns impede with such study design considerations.

Cone-based computed tomography is widely used to analyze the bone quantity in the maxillofacial region, while its application for soft-tissue imaging has been questioned (Scarfe *et al.,* 2006). The gold standard to visualize the inflammatory changes in the nasal and paranasal sinus mucosa is the computed tomography (CT) or magnetic resonance imaging (MRI). Both techniques are proven accurate for evaluation of the pathophysiology of paranasal sinusitis (Larheim, 2006). However, recent data confirmed the usefulness of CBCT in assessing and evaluating soft tissues (Brüllmann *et al.,* 2011; Janner *et al.,* 2011; Larheim, 2006; Barriviera *et al.,* 2009; Januario *et al.,* 2008; Fu *et al.,* 2010). Data from the present analysis on SM thickness demonstrated the potential use of CBCT imaging for the evaluation of the soft tissue conditions in the maxillary sinus.

In the current study population, an age difference was observed between DG and EG, which is most likely related to the increased tooth loss in older patients (Schürch *et al.,* 2004). The strong association of a significantly greater sinus membrane thickness and age in EG was confirmed by several previous data sets (Iwabuchi *et al.,* 1997; Vallo *et al.,* 2010; Photikum *et al.,* 2012).

The current study was initiated based on the assumption of an association of periodontal disease and furcation involvement with sinus membrane thickness assessed from CBCT images. While the 2nd premolar site did not reveal differences between the dentate and the edentulous group, SM adjacent to molar sites showed a thickening in EG, particularly with close proximity of the root tips to the sinus floor. The clinical parameters PPD and FI, however, failed to predict SM thickening in this case series with advanced periodontal destruction in the maxillary posterior region. In contrast, the presence of additional findings, such as periapical lesions, overfill of the root canal or foreign bodies in the DG revealed a significant association with sinus membrane thickness. Several authors investigated the conditions of the Schneiderian membrane with different radiographic methods and reported discriminative results. An association between mucosal thickening and periapical lesions, furcation involvements, and vertical infrabony defects was observed when analyzing panoramic radiographs from dentate and edentulous sites (Vallo *et al.,* 2010). Further, a correlation was found between severe periodontal bone loss (assessed from CBCT) and mucosal thickening, while no such correlation was observed for the presence of periapical lesions and root canal fillings (Photikum *et al.,* 2012). Brüllmann *et al.* reported a strong association between SM thickening and periodontitis (with PPD > 3 mm) or decayed and non-vital teeth (Brüllmann *et al.,* 2011). Although the basal mucosal wall was primarily affected, total mucosal swelling was rare, which is in agreement with the observations in the present study with smaller SM values at the medial wall (RpC).

In the present study, a strong association of the bone height above the root tips in the molar region and SM thickness was documented. The close anatomical relationship between the root tips and the maxillary sinus may support the spread of an endodontic infection to the sinus (Ariji *et al.,* 2006). Periapical radiolucencies, i.e., endodontic lesions, found in the DG are a potential cause of an increased sinus membrane thickness. The influence of endodontic infections on the sinus membrane thickness was recently confirmed (Bornstein *et al.,* 2012). In this study comparing CBCTs from subjects with and without apical pathology at maxillary premolars or molars, SM thickening was found particularly in the vicinity of roots with apical lesions (Bornstein *et al.,* 2012).

Conclusions

The Schneiderian membrane revealed a more pronounced thickness in CBCT images when comparing maxillary molar sites with the corresponding edentulous regions. Although clinical periodontal parameters failed to predict SM thickening, the observed association of endodontic-related findings with SM thickness confirmed previous research.

Acknowledgments

The authors gratefully acknowledge the support by Andy Schötzau and Urs Simmen with the statistical analyses.

References

Arias-Irimias, O., Barona-Dorado, C., Santos-Marino, J.A., Martinez-Rodriguez, N. and Martinez-Gonzalez, J.M. Meta-analysis of the etiology of odontogenic maxillay sinusitis. *Medicina Oral Patologia Oral Y Cirugia Bucal* 2010; **15**: e70-73.

Ariji, Y., Obayashi, N., Goto, M., *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. *Clinical Oral Investigations* 2006; **10**:35-41.

Barriviera, M.D., Januario, A.L., Faber, J. and Bezera, A.C.B. A new method to assess and measure palatal masticatory mucosa by cone-beam computerized tomography. *Journal of Clinical Periodontology* 2009 **36**:564-568.

Brook, I. Sinusitis of odontogenic origin. *Otolaryngology Head and Neck Surgery* 2006 **135**:349-355.

Bornstein, M.M., Wasmer, J., Sendi, P., Janner, S.F., Buser, D. and von Arx, T. Characteristics and dimensions of the Schneiderian membrane and apical bone in maxillary molars referred for apical surgery: a comparative radiographic analysis using limited cone beam computed tomography. *Journal of Endodontics* 2012; **38**:51-57.

Brüllmann, D.D., Schmidtmann, I., Hornstein, S. and Schulze, R.K. Correlation of cone beam computed tomography (CBCT) findings in the maxillary sinus with dental diagnoses: a retrospective cross-sectional study. *Clinical Oral Investigations* 2011; **16**:1023-1029.

De Pablo, P., Chapple, I.L., Buckley, C.D. and Dietrich, T. Periodontitis in systemic rheumatic diseases. *Nature Reviews Rheumatology* 2009; **5**:218-224.

Fu, J.H., Yeh, C.Y., Chan, H.L., Tatarakis, N., Leong, D.J.M. and Wang, H.L. Tissue biotype and its relation to the underlying bone morphology. *Journal of Periodontology* 2010; **8**:569-574.

Gray, H. Osteology. In: Gross, H., (Ed). *Gray's anatomy.* 28th ed. Philadelphia: Lea and Febiger, 1970.

Hamp, S.E., Nyman, S., Lindhe, J. Periodontal treatment of multirooted teeth. Results after 5 years. *Journal of Clinical Periodontology* 1975;**2**:126-135.

Incaudo, G.A. and Wooding, L.G. Diagnosis and treatment of acute and subacute sinusitis in children and adults. *Clinical Reviews in Allergy and Immunology* 1998; **16**:157-204.

Iwabuchi, Y., Hanamure, Y., Ueno, K., Fukuda, K. and Furuta, S. Clinical significance of asymptomatic sinus abnormalities on magnetic resonance imaging. *Archives of Otolaryngology - Head and Neck Surgery* 1997; **123**:602-604.

Janner, S.F.M., Caversacchio, M.D., Dubach, P., Sendi, P., Buser, D. and Bornstein, M.M. Characteristics and dimensions of the Schneiderian membrane: a radiographic analysis using cone beam computed tomography in patients referred for dental implant surgery in posterior maxilla. *Clinical Oral Implants Research* 2011; **22**:1446-1453.

Januario, A.L., Barriviera, M. and Duarte, W.R. Soft tissue cone-beam computed tomography: a novel method for the measurement of gingival tissue and the dimensions of the dentogingival unit. *Journal of Esthetic and Restorative Dentistry* 2008; **20**:366-374.

Larheim, T.A. and Westesson, P.L. Paranasal sinuses. In: Larheim TA, Westesson PL (Eds). *Maxillofacial Imaging*. Berlin. Springer, 2006.

Logan, G. and Bocklebank, L. An audit of occipitomental radiographs. *Dentomaxillofacial Radiology* 1999; **28**:158-161.

Maillet, M., Bowles, W.R., McClanahan, S.L., John, M.T. and Ahmad, M. Cone-beam computed tomography evaluation of maxillary sinusitis. *Journal of Endodontology* 2011; **37**:753-757.

Mombelli, A. and Meier, C. On the symmetry of periodontal disease. *Journal of Clinical Periodontology* 2001; **28**:741-755.

Mozzo, P., Procacci, C., Tacconi, A., Martini, P.T. and Andreis, I.A. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. *European Journal of Radiology* 1998; **8**:1558-1564.

Nair, U.P. and Nair, M.K. Maxillary sinusitis of odontogenic origin: cone-beam volumetric computerized tomography-aided diagnosis. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology Endodontology* 2010; **110**: e53-57.

Page, R.C. and Kornman, K.S. The pathogenesis of human periodontitis: an introduction. *Periodontology 2000* 1997; **14**:9-11.

Pazera, P., Bornstein, M.M., Pazera, A., Sendi, P. and Katsaros, C. Incidental maxillary sinus findings in orthodontic patients: a radiographic analysis using cone-beam computed tomography (CBCT). *Orthodontics and Craniofacial Research* 2011; **14**:17-24.

Phothikum, S., Suphanantachat, S., Chuenchompoonut, V. and Nispakakultorn, K. Cone beam computed tomographic evidence of the association between periodontal bone loss and mucosal thickening of the maxillary sinus. *Journal of Periodontology* 2012; **83**:557-564.

Scarfe, W.C., Farman, A.G. and Sukovic, P. Clinical applications of cone-beam computed tomography in dental practice. *Journal of the Canadian Dental Association* 2006; **72**:75-80.

Schürch, E. Jr. and Lang, N.P. Periodontal conditions in Switzerland at the end of the 20th century. *Oral Health and Preventive Dentistry* 2004; **2**:359-368.

Shrout, P.E. and Fleiss, J.L. Intraclass correlations: uses in assessing rater reliability. *Psychological Bulletin* 1979; **86**:420-428.

Sun, W.L., Chen, L.L., Zhang, S.Z., Wu, Y.M., Ren, Y.Z. and Qin, G.M. Inflammatory cytokines, adiponectin, insulin resistance and metabolic control after periodontal intervention in patients with type 2 diabetes and chronic periodontitis. *Journal of Internal Medicine* 2011; **50**:1569-1574.

Tarnow, D. and Fletcher, P. Classification of the vertical component of furcation involvement. *Journal of Periodontology* 1984; **55**:283-284.

The SEDENTEXCT consortium project report. Radiation Protection: Cone beam CT for dental and maxillofacial radiology. Evidence based guidelines.http://www.sedentexct.eu/files/guidelines_final.pdf

Tonetti, M.S., D'Aiuto, F., Nibali, et al. Treatment of periodontitis and endothelial function. *New England Journal of Medicine* 2007; **356**:911-920.

Vallo, J., Suominen-Taipale, L., Huumonen, S., Soikkonen, K. and Norblad, A. Prevalence of mucosal abnormalities of the maxillary sinus and their relationship to dental disease in panoramic radiography: results from Health 2000 Health Examination Survey. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology Endodontology* 2010; **109**:e80-87.

Walter, C., Kaner, D., Berndt, D.C., Weiger, R. and Zitzmann, N.U. Three-dimensional imaging as a preoperative tool in decision making for furcation surgery. *Journal of Clinical Periodontology* 2009; **14**:35-41.

Walter, C., Weiger, T. and Zitzmann, N.U. Periodontal surgery in furcation-involved maxillary molars revisited – an introduction for guidelines for comprehensive treatment. *Clinical Oral Investigations* 2010a; **15**:9-20.

Walter, C., Weiger, C. and Zitzmann, N.U. Accuracy of three-dimensional imaging in assessing maxillary molar furcation involvement. *Journal of Clinical Periodontology* 2010b; **37**:436-441.